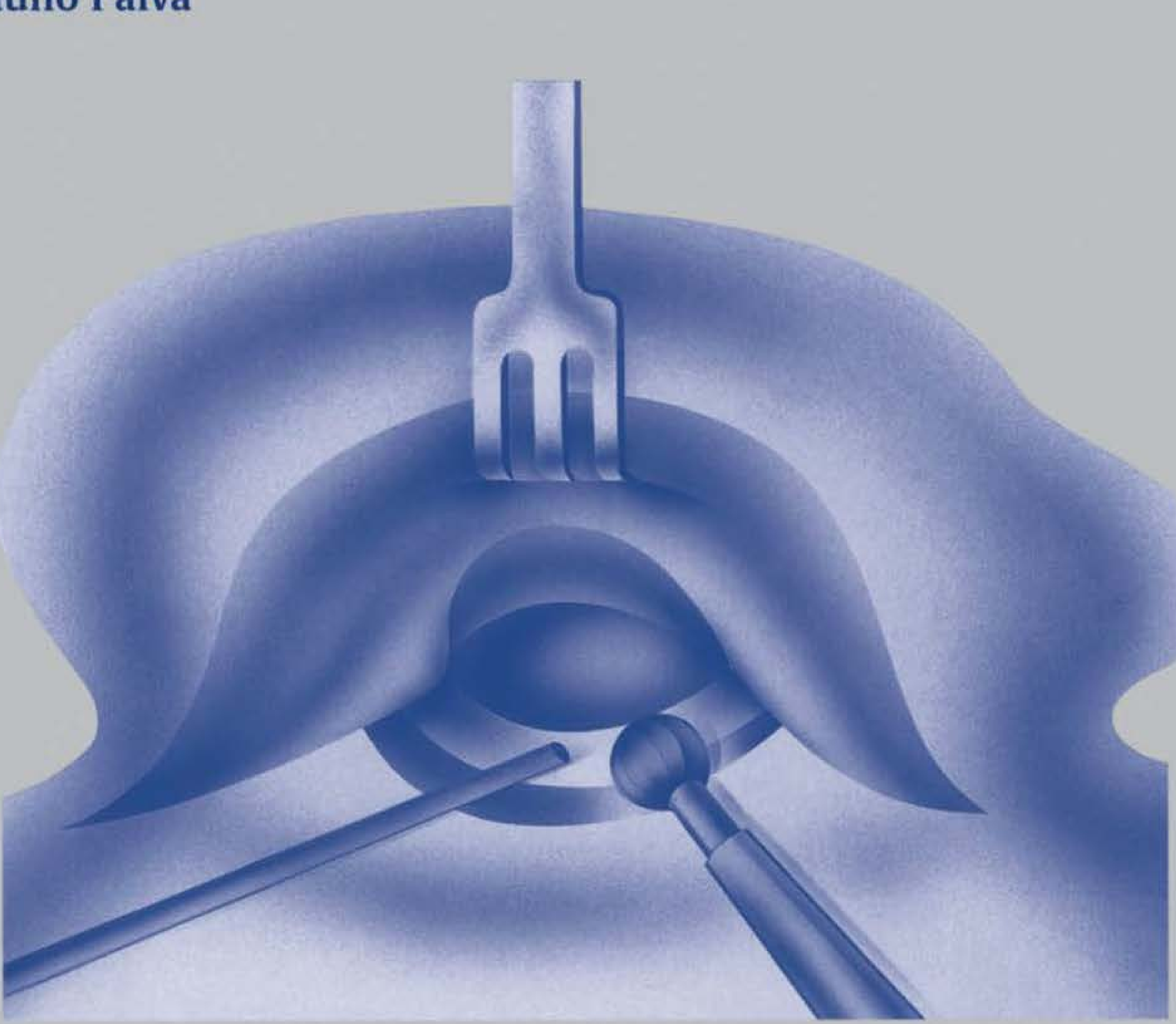
Manual of Middle Ear Surgery

Vol. 2: Mastoid Surgery and Reconstructive Procedures

Mirko Tos

Foreword by
Tauno Palva



Thieme

Manual of Middle Ear Surgery

Volume 2

Manual of Middle Ear Surgery

Volume 1:
Approaches,
Myringoplasty,
Ossiculoplasty,
and Tympanoplasty

Volume 2:
Mastoid Surgery
and Reconstructive
Procedures

Georg Thieme Verlag
Stuttgart · New York

Thieme Medical Publishers, Inc.
New York

Manual of Middle Ear Surgery

Volume 2: Mastoid Surgery and Reconstructive Procedures

Mirko Tos

Foreword by
Tauno Palva

1040 illustrations

1995
Georg Thieme Verlag
Stuttgart · New York
Thieme Medical Publishers, Inc.
New York

Mirko Tos, M. D. PhD.
Professor and Chairman, Department of Otorhinolaryngology
Gentofte Hospital
University of Copenhagen
Niels Andersens Vej 65, 2000 Hellerup
Denmark

Library of Congress Cataloging-in-Publication Data

Tos, Mirko:
Manual of middle ear surgery / Mirko Tos, [Drawings by Regitze Steinbruch]. –Stuttgart; New York : Thieme.

Vol. 1. Approaches, myringoplasty, ossiculoplasty and tympanoplasty / foreword by Michael E. Glasscock III. – 1993

Vol. 2. Mastoid Surgery and Reconstructive Procedures / foreword by Tauno Palva – 1995

Important Note: Medicine is an ever-changing science undergoing continual development. Research and clinical experience are continually expanding our knowledge, in particular our knowledge of proper treatment and drug therapy. Insofar as this book mentions any dosage or application, readers may rest assured that the authors, editors and publishers have made every effort to ensure that such references are in accordance with the state of knowledge at the time of production of the book. Nevertheless this does not involve, imply, or express any guarantee or responsibility on the part of the publishers in respect of any dosage instructions and forms of application stated in the book. Every user is requested to examine carefully the manufacturers' leaflets accompanying each drug and to check, if necessary in consultation with a physician or specialist, whether the dosage schedules mentioned therein or the contraindications stated by the manufacturers differ from the statements made in the present book. Such examination is particularly important with drugs that are either rarely used or have been newly released on the market. Every dosage schedule or every form of application used is entirely at the user's own risk and responsibility. The authors and publishers request every user to report to the publishers any discrepancies or inaccuracies noticed.

Drawings by Regitze Steinbruch
Cover drawing by Renate Stockinger

Some of the product names, patents and registered designs referred to in tis book are in fact registered trademarks or proprietary names even though specific reference to this fact is not always made in the text. Therefore, the appearance of a name without designation as proprietary is not to be construed as a representation by the publisher that it is in the public domain.

This book, including all parts thereof, is legally protected by copyright. Any use, exploitation or commercialization outside the narrow limits set by copyright legislation, without the publisher's consent, is illegal and liable to prosecution. This applies in particular to photostat reproduction, copying, mimeographing or duplication of any kind, translating, preparation of microfilms, and electronic data processing and storage,

© 1995 Georg Thieme Verlag, Rüdigerstraße 14,
D-70469 Stuttgart, Germany
Thieme Medical Publishers, Inc., 381 Park Avenue South, New York, NY 10016

Typesetting by primustype R. Hurler, D-73274 Notzingen

Printed in Germany
by Karl Grammlich, D-72124 Pliezhausen

ISBN 3-13-114901-9 (GTV, Stuttgart)
ISBN 0-86577-589-3 (TMP, New York)
eISBN 9783131747211

4 5 6

Foreword

In this second volume to Manual of Middle Ear Surgery, Mirko Tos has completed a very ambitious task. His intention has been different than that of many other authors of earlier textbooks. Being an experienced ear surgeon himself, having had contacts for many decades with the foremost colleagues in otology, and having read thousands of publications, he has described and illustrate in minute detail all meaningful surgical techniques for chronic inflammatory ear disease and its sequelae. This is an enormous task, which would usually have to be accomplished with a long list of co-authors. One cannot but admire Mirko Tos, who, in addition to leading a University department, operating, and doing research, has alone been able to complete the two volumes during the last three years.

The first volume of this Manual describes the surgical techniques for reconstruction of the middle ear, and they form an integral part of knowledge that must be incorporated in the techniques described in the second volume, which deals with the deseased mastoid. Every posible aspect of mastoid surgery has been thoroughly discussed. The details are illustrated with 1040 figures—and everyone perusing surgical techniques knows that illustrations are even more valuable than words. Mirko Tos has painstakingly sketched all figures himself, and be finalized by a competent artist. This guarantees that the illustrations are based on knowledge acquired both in the temporal bone dissection room and in the operating room.

Volume 2 in its 22 chapters covers the historic aspects of technical developments in ear surgery even more than Volume 1. This is in a way natural because tympanoplastic surgery was really born in the early 1950s, whereas techniques used even today for mastoid surgery date back to the early part of this century. The older generation of ear surgeons who have lived in the midst of this active and ever-improving field know firsthand the step-wise progress ear surgery has made during the last 45 years. As specialists in the early 1950s, our basic knowledge consisted of the "old" methods, which were well discussed, e.g., in the first edition (1959) of Shambaugh's Surgery of the Ear. These procedures and those developed during the two first decades of reconstruction surgery are often poorly known by the younger generation of ear surgeons. Mirko Tos clarifies the variety of terms used in connection with the same or a different surgical method and provides a clear-cut presentation of basic older techniques, some of which are still as such, or modified, applicable to present-day reconstruction techniques. We must also remember that in many less-developed countries with limited possibilities for aftercare, the basic old method in dealing with the mastoid may be the preferred ones even today.

In addition to being useful to specialists, this book is an excellent guide for surgeons in training. Especially in university departments, the two volumes are invaluable in the teaching programs for ear surgery. When the trainee seminars are led by an experienced ear surgeon, the "why" questions regarding various procedures become easily answered and understood when they are studied using this Manual as a background. From the variety of possible methods, the best can be chosen for departmental routines. For certain exceptional problems, some little used additional techniques may be applied to arrive at a satisfactory outcome.

The volumes of this Manual emphasize the great variety of surgical techniques we have at our disposal to arrive at the desired end result: a well—functioning safe ear that resembles the original healthy model as much as possible. A frequent study of these volumes also helps an individual ear surgeon in the selection of the most suitable operation method for his or her own training and experience. During the course of years, with increasing experience and skill, even the most refined techniques will find their way into everyday practice.

Tauno Palva
Professor Emeritus of Otolaryngology,
University of Helsinki, Finland

Preface

The second volume of the Manual of middle ear surgery is structured according to the same principles and has the same goal as Volume 1 — to teach otologists-in-training various mastoidectomy and reconstructin procedures, using step-by-step demonstrations of the surgery.

Besides the several canal wall–down mastoidectomy methods, established before the tympanoplasty era, numerous new canal wall–up mastoidectomy methods have been developed over the last 40 years. All methods are illustrated with step-by-step drawings that trace the procedure to the point at which the disease has been completely removed. Further illustrations show the reconstructions of the tympanic cavity and the attic, rounding out the first part of the book with many reconstruction figures.

In the second part of the book the reconstructions of the ear canal wall and the mastoid cavity are illustrated. Searching through the literature revealed an amazingly large number of cavity obliteration methods, which have been described and classified. From the temporal bone dissection courses, I have learned that otologists-in-training need to practice the reconstruction methods as much as they do the drilling methods. Therefore, such methods are covered extensively in the book.

Removal of cholesteatoma is the main goal and the most difficult part of mastoid surgery. It cannot be practiced on temporal bones and is thoroughly described and accompanied by step-by-step illustrations of several mastoidectomy methods.

In no other surgical speciality can a chronic disease be operated on using so many, often completely different methods, all correct. Because the canal wall–down mastoidectomy — as one extreme — and the classic intact canal wall mastoidectomy — the other extreme — are widely accepted as the methods of choice by two major groups of otosurgeons, the modifications of these two extremes, applied by the third group of otosurgeons in an attempt to bring the two extremes closer to each other, also deserve thorough illustration. For the same reason I have included previously commonly used, but nowadays abandoned, canal wall–down mastoidectomy methods with preservation of the bony bridge.

The mastoidectomy and reconstruction methods are classified in groups and subgroups, taking as many factors as possible into consideration, which is the second important goal of the book. Such classification is much more complex and difficult than the classification of myringo- and ossiculoplasties described in Volume 1, and it was necessary to define several surgical transmastoid or transmeatal procedures in the attic, such as anterior, posterior, and lateral atticotympanotomy and others. I hope that at least some of them will be accepted and used. As in Volume 1, I often connected the modifications of the mastoidectomy and reconstruction methods to the names of the authors who described or promoted them. In this respect the book may be considered a historical review of middle ear surgery. In Volume 2 it was necessary to illustrate the evolution of the mastoidectomy methods and include, more often than in Volume 1, my personal view on the long-term stability of the reconstruction methods. Therefore, this volume, still trying to be a surgical manual for *all* methods became increasingly polemic.

All illustrations in Volume were made in the same way as those in Volume 1, I sketched each illustration on parchment paper, and the artist Regitze Steinbruch copied and redren them. Even with our excellent cooperation and increased experience with drawings of the middle ear gained during the preparation of Volume 1, it took us twice as long to produce approximately the same number of drawings for the much more complicated mastoidectomy procedures.

Most of the intermediate surgical steps of the mastoidectomy and reconstruction procedures have not been published as illustrations in books or journals. To make anatomically correct step-by-step drawings, videos, collected over years, were reviewed and some procedures repeated on temporal bones. Videos from my friends were of great help and enabled me to redraw their methods much more precisely than would have been possible from their publications. The staffs of the Audiovisual Department, Gentofte Hospital, and the Gentofte Hospital Library have been very helpful.

Dr. Simon Baer, since Volume 1 a busy consultant ENT Surgeon in Sussex, UK, provided extremely valuable, assistance on language questions. My secretary Inge Joost typed and corrected the manuscript.

Several important topics on fixations and complications that could not be included in Volume 2 will be presented in Volume 3. They are tympanosclerotic, bony, and fibrous fixations, retractions, atelectasis, adhesive otitis, Eustachian tube surgery, labyrinthine fistula, facial palsy, and petrous bone cholesteatoma. Stenosis, atresia and cholesteatoma of the external ear canal, and some other new developments will also be included.

Mirko Tos *April 1995*

Contents

Part I Mastoidectomies 1

1 Definitions and Classifications of Mastoidectomy 2
- Atticotomy 2
- Atticoantrotomy 4
- Bondy's Operation 5
- Cortical Mastoidectomy 9
- Conservative Radical Operation 10
- Classical Radical Operation 10
- Tympanomastoidectomy 11

Approaches and Routes 11
- Transcortical Route 11
- Transmeatal Route 12
- Approaches and Mastoidectomies 12
- Routes and Approaches 12

Canal Wall–Up and Canal Wall–Down Mastoidectomies 14
- Open and Closed Techniques 14
- Classic Canal Wall–Up Mastoidectomy .. 15
- Modifications of Intact Canal Wall Mastoidectomy 16
- Canal Wall–Down Mastoidectomies 21
- Modification of Canal Wall–Down Mastoidectomy 21

2 Anatomy 23

Surgical Anatomy of the Temporal Bone ... 23
The Extracranial Surface of the Temporal Bone 23
The Mastoid Process– The Mastoidectomy 26
- Middle Cranial Fossa Dural Plate 27

The Sigmoid Sinus 28
- The Sinodural Angle 29
- Körner's Septum 30

Mastoid Antrum 31
The Labyrinth 31
- The Posterior Fossa Dural Plate 33
- Facial Recess 33

The Attic 35
The Epitympanic Sinus 36
Posterior Tympanum 38
Tympanic Diaphragm 40
- Mucosal Folds 40
- Prussak's Space 42

Mesotympanum 43
The Tympanic Orifice of the Eustachian Tube 44
Hypotympanum 46
The Facial Nerve 48

3 The Pneumatic System of the Temporal Bone 50

Hereditary and Environmental Pneumatization Theories 51
The Size of Air Cells and Previous Disease . 54
The Pneumatization Process 54
The Air Cell Tracts 54
Mastoid Air Cells 55
Perilabyrinthine Cells 56
- Superior Perilabyrinthine Cell Tracts 56

Sublabyrinthine Cell Tracts 57
Precochlear or Inferior Prelabyrinthine Cell Tracts 58
Clinical Importance of Cell Tract Connections 58
The Constricted Mastoid Process 60
The Question of Cause and Effect 61

4 Basic Mastoidectomy Techniques 62

The Drilling Techniques 62
Damage Resulting from the Cutting Burr .. 62
- Damage to Soft Tissue 62
- Damage to the Ear Canal Skin Flaps 63

Exposure of the Dura 63
- Damage to the Middle Fossa Dura 66

Repair of Dural Defects 66
- Avoidance of Dural Lesions 68

Exposure of the Sigmoid Sinus 69
- Bill's Island Method 72
- The Eggshell Method 73
- Total Exposure of the Sigmoid Sinus 74

Bleeding from the Sigmoid Sinus 76
Total Exposure of the Posterior Fossa Dura 79
Entering the Mastoid Antrum 81
Exposure of the Sinodural Angle 84

  - Bleeding from the Emissary Vein and Superior Petrosal Sinus 84
- Exenterating the Mastoid Tip Cells 86
- Exenterating the Perilabyrinthine Cells 88
  - Necessity of Exenterating of Perilabyrinthine Cells 90
- Cholesteatoma Removal from the Perilabyrinthine Space 90

5 Simple (Cortical) Mastoidectomy 96
  - Definitions 96
  - History 96
  - Incidence of Mastoidectomy 97
- Indications for Simple Mastoidectomy in Acute Mastoiditis 98
  - Absolute Indications 98
  - Relative Indications 98
- Simple Mastoidectomy Technique in Infants 99
  - Postoperative Care 102
- Cortical Mastoidectomy Technique in Older Children 102
  - The Size of the Mastoid Air Cells and Mastoidectomy 102
  - Entering the Mastoid Antrum 102
  - Complications of Cortical Mastoidectomy 103
  - Late Sequelae after Mastoidectomy 104
  - Indications for Cortical Mastoidectomy other than Coalescent Mastoiditis 104

6 Classic Intact Canal Wall Mastectomy .. 106
  - Definition 106
  - Evolution of Classic Intact Canal Wall Mastoidectomy 106
- Preservation of the Soft Meatal Wall 106
- Preservation of the Bony Ear Canal Wall 108
  - Further Development of the Posterior Atticoantrotomy 110
- Surgical Technique 110
  - Incision 110
  - Ear Canal Skin Elevation 110
- Mastoidectomy 111
  - Thinning the Posterior Ear Canal Wall ..112
- Lateral Atticotympanotomy 113
- Posterior Atticotympanotomy 115
  - Removing the Posterior Buttres 118
  - Posterior Atticotympanotomy with Absent Incus 118
  - Complications of Posterior Atticotomy 120
  - Extended Posterior Atticotympanotomy, Transmastoid Hypotympanotomy 121
- Transcortical Anterior Atticotympanotomy 122
  - Anterior Enlargement of the Mastoid Cavity 122
  - Unroofing the Attic 123
  - Entering the Epitympanic Sinus 124
- Transmeatal Anterior Atticotympanotomy (Morimitsu) 125
- Removal of Cholesteatoma 128
  - Conservative Cholesteatoma Removal 129
  - Removal of Attic Cholesteatoma 129
  - Attic Cholesteatoma in Intact Ossicular Chain 131
  - Removal of Attic Cholesteatoma in a Disrupted Ossicular Chain 133
  - Removal of Sinus and Tensa Retraction Cholesteatoma 135
- Scutumplasty 137
  - Scutumplasty with Autogenous Cartilage 137
  - Allogenous Cartilage 141
  - Bone in Scutumplasty 143
  - Scutumplasty Using Autogenous Bone Paté 145
  - Scutumplasty with Biocompatible Materials 146
- Postoperative Attic Retraction 147
  - Causes of Retraction 147
  - Mechanisms of Retraction. 148
  - Appearance and Progression of Retraction 149
- Cavity Obliteration Behind the Intact Canal Wall 153
  - The Honda Partial Obliteration Method 155

7 Modified Combined Approach Tympanoplasty 156
  - Definition 156
- Surgical Technique 156
  - Approach 156
- Removal of Attic Cholesteatoma 157
  - Otosclerosis Drilling 157
- Transmeatal Atticotomy 158
- Transcortical and Transmeatal Anterior Atticotympanotomy 166
- Removal of Large Attic Cholesteatoma 168
- Reconstruction of Atticotomy with an Intact Chain 172

Attic Cholesteatoma with Defective Ossicular Chain 175
  Transmeatal Anterior Atticotympanotomy 176
Bougienage of the Eustachian Tube 177
  Reconstruction 178
Removal of Large Attic Cholesteatoma Involving the Incus and Malleus 178
Reconstruction of Atticotomy 181
  Displacement of the Bridge 183
  Reconstruction of the Atticotomy with a Displaced Bridge 186
  Reconstruction of the Atticotomy with a Missing Bridge 187
Removal of Sinus Cholesteatoma 189
  Reconstruction in Cases of Sinus Cholesteatoma 192
  Removal of Tensa Retraction Cholesteatoma 192
  Reconstruction of Ears with Tensa Retraction Cholesteatoma ... 193
The Philosophy of Modified Intact Canal Wall Mastoidectomy 194

8 Temporary Displacement or Removal of the Bony Ear Canal Wall 196

Temporary Displacement of the Bony Ear Canal Wall 196
  Osteoplastic Mastoidectomy (Schnee) ... 196
  Posterior Wall Displacement 199
  Richards' Mobile Bridge Technique 200
Temporary Removal of the Bony Ear Canal Wall 202
  Temporary Meatotomy 202
  Osteoplastic Epitympanotomy (S. Wullstein) 202
  Reconstruction of the Osteoplastic Epitympanotomies 203
  Osteoplastic Epitympanotomy and Mastoidectomy 205
  Portmann's Technique 205
Osteoplastic Meatoantrotomy (Feldmann) 206
  Obliteration in Temporary Bony Ear Canal Wall Removal 210
The Babighian Posterior and Attic Wall Osteoplasty 211

9 Tympanomeatoplasty with Preservation of the Bony Bridge (Wigand) 214

The Wigand Technique 214
  Cholesteatoma Removal in Tympanomeatoplasty 218
Reconstruction of the Tympanomeatoplasty 218

10 Transmeatal Anterior Atticotympanotomy and Transcortical Mastoidectomy (Farrior) 222

  Definitions 222
The Farrior Technique 222
  Reconstruction of the Anterior Atticotympanotomy and Mastoidectomy 225
The Antrum Exclusion and Attic elimination On-Demand Technique (Olaizola) 227
The Wide External Auditory Canal Technique (Bellucci) 229

11 Transcortical Canal Wall–Down Mastoidectomy 230

  Historical Remarks 230
  Definitions 230
Bondy's Operation 231
  Reconstruction in Bondy's Operation ... 233
  Preservation of the Cholesteatoma Matrix 234
  The Sanna Modification 234
Canal Wall–Down Mastoidectomy with Removal of the Bridge 235
  Removal of the Bony Ear Canal Wall ... 235
  Smoothing the Superior and Anterior Cavity Walls 237
  Removal of the Facial Ridge 237
Partial Preservation of the Bridge 239
Removal of Attic Cholesteatoma in Canal Wall–Down Mastoidectomy 241
Removal of Sinus Cholesteatoma in Canal Wall–Down Mastoidectomy 242
  Removal of Tensa Retraction Cholesteatoma 243
Preservation of an Intact Bridge 245
  Displacement of the Intact Bridge 246

12 Transmeatal Canal Wall–Down Mastoidectomy 247

  Definitions 247
Outside-In Transmeatal Canal Wall–Down Mastoidectomy 248
  Removal of Attic Cholesteatoma in Transmeatal Outside-In Mastoidectomy 253
Transmeatal Inside-Out Canal Wall–Down Mastoidectomy 255

Retrograde Mastoidectomy with Massive Erosion of the Lateral Attic Wall 256
Retrograde Mastoidectomy on Demand 258

13 Endaural Canal Wall–Down Mastoid Surgery 262
History of Endaural Surgery 262
Techniques of Endaural Canal Wall–Down Surgery 263
Techniques with Removal of the Bridge 267
Reconstructions in Cases with No Bridge 268
Various Methods of Myringoplasty, Ossiculoplasty, and Attic Ventilation 273
Partial or Total Obliteration of the Attic 274
Preservation of an Intact Bridge in Endaural Mastoid Surgery 275
Inside-Out Mastoidectomy with Preservation of the Bridge 275
Retrograde Endaural Mastoidectomy on Demand 277
Reconstruction of the Attic 278
The Paparella Intact Bridge Tympanomastoidectomy 282

Part II Reconstructions **285**

14 Classification of Reconstruction Methods 286
Closed and Open Techniques 287
Reconstruction of the Tympanic Cavity and the Attic 290
Myringo-Ossiculoplasty in Canal Wall-Up Mastoidectomy 290
Myringo-Ossiculoplasty in Canal Wall-Down Mastoidectomy 290
Relationship Between Attic Reconstruction and the Mastoid Cavity 292

15 The Open Cavity 294
Epithelial Covering of the Open Cavity 294
Free Split-Skin and Full-Thickness Skin Grafts 294
Pedicled Skin Grafts 295
Pedicled Skin-Subcutis Skin Grafts 295
Pedicled Ear Canal Skin Flaps 299
The Körner Flap 299
The Surdille Flap 301
The Stacke Flap 302
Meatoplasty 303
Endaural Approach 303
Retroauricular Approach 305
Meatoplasty and Obliteration 310
Modification of the Palva flap and Meatoplasty 312

16 Mastoid Tip Removal 315
Guilford's Method 315
Obliteration of the Mastoid Tip Area 317
Retroauricular Approach 318
Reducing the Upper Part of the Cavity 322

17 Reconstruction of the Posterior Ear Canal Wall 324
Total Reconstruction with Ventilation of the Cavity 324
Criteria for Cavity Ventilation 324
Reconstruction with Fascia 325
Retroauricular Approach, with Palva Flap 325
Endaural Approach 328
Reconstruction with Autogenous Cartilage 329
Tragal Cartilage 329
Reconstruction with Allogenous Cartilage 331
Septal Cartilage 331
Knee Cartilage 332
Reconstruction with Autogenous Bone 333
Mastoid Cortical Bone 333
Iliac Crest Bone 335
Bone Paté 335
Allogenous Ear Canal Wall Tranplantation 338
Reconstructions with Biocompatible Materials 339
Proplast 339

Biocompatible Glass Ceramic Material 339
Glass Ionomer Cement 339
Hydroxyapapite 339
Partial Reconstruction of the Ear Canal Wall 343

18 Obliteration of the Cavity with Pedicled Muscle Flaps 346
Superiorly Based Flaps 346
The Rambo Flap 346
The Freerichs and Williams Flap 349
The Tos Bipartite Flap 351
The Guilford Superior Pedicled Flap 354
The Elbrønd Flap 355
The Turner Temporalis Muscle Double Flap 356
Posterosuperiorly Based Musculofascial Flap 359
Whitcher's Tripartite Flap 361
Atrophy of the Temporalis Muscle 362
Anteriorly Based Muscle Flaps 364
Mosher Flap and Popper Flap 364
The Palva Flap 366
Enlargement of the Palva Flap 368
Inferiorly Based Flaps 372
Meurmann's Musculoperiosteal Flap 372
The Guilford Inferiorly-Based Flap 374
The Hilger and Hohmann Flap 375
The Naumann Large Inferiorly Pedicled Flap 377
Farrior Inferior Pedicled Flap 379
Complications 380
Combinations of Pedicled Subcutis Muscle Obliteration Techniques 382

19 Cavity Obliteration with Cartilage 383
Autogenous Cartilage 383
Obliteration in Canal Wall–Up Mastoidectomy 383
Obliteration in Canal Wall–Down Mastoidectomy 386
Autogenous Cartilage in Combined-Graft Obliteration 386
Perichondrium-Palisaded Cartilage Mastoidplasty (Heermann) 388
Partial Obliteration 389
Allogenous Cartilage 389
Allogenous Septal Cartilage 389
Allogenous Knee Cartilage 391
Allogenous Costal Cartilage 391

20 Cavity Obliteration with Bone 393
Heterotopic Cancellous Bone 393
Iliac Crest Cancellous Bone 393
Tibial Crest Cancellous Bone 395
Orthotopic Mastoid Bone 396
Obliteration with Bone Chips 397
Obliteration with Bone Plates 397
Obliteration with Bone Paté 400
Allogenous Cancellous Bone 401

21 Obliteration with Biocompatible Materials 404
Inorganic Bovine Bone 404
Obliteration with Methacrylate 404
Ceramics 405
Plaster of Paris 405
Plasticine 408
Triosite 408
Hydroxyapatite 410
Glass Ionomer Cement 413

22 Obliteration with a Fat Graft 414
Possible Application of Fat Graft 414
Intact Canal Skin 414
Intact Bony Canal Wall 414
Reconstructed Ear Canal Wall 415
Risk of AIDS 415

References 417
Index 425

Part I

Mastoidectomies

1 Definitions and Classifications of Mastoidectomy

Many types of mastoidectomy have been described in the literature, both prior to and since the beginning of the tympanoplasty era. The various terms used by different surgeons need to be explained, defined, and coordinated, so that an acceptable terminology for mastoidectomy can be applied—at least in this book. This terminology should include in a logical way all variations of mastoidectomy methods and all reconstruction methods; it should also take into consideration various surgical approaches and routes.

Several basic terms, such as atticotomy, atticoantrotomy, simple mastoidectomy, conservative radical operation, classic radical operation, and tympanomastoidectomy, have often been used and will be defined below.

Atticotomy

Atticotomy (epitympanotomy) denotes opening of the attic, performed through the transmeatal route. The lateral wall of the attic is drilled away, and the lateral attic is exposed. This can be performed in several ways, resulting in various modifications:

- Preservation of the bony bridge, by drilling superior to the bony annulus and widening it towards the tegmen tympani (Fig. **1**).
- Total removal of the bony bridge together with the lateral attic wall up to the tegmen tympani, exposing the lateral attic, the ossicles, and the ligaments (Fig. **2**). In cases of resorption of the ossicles or removal of the remnants of the

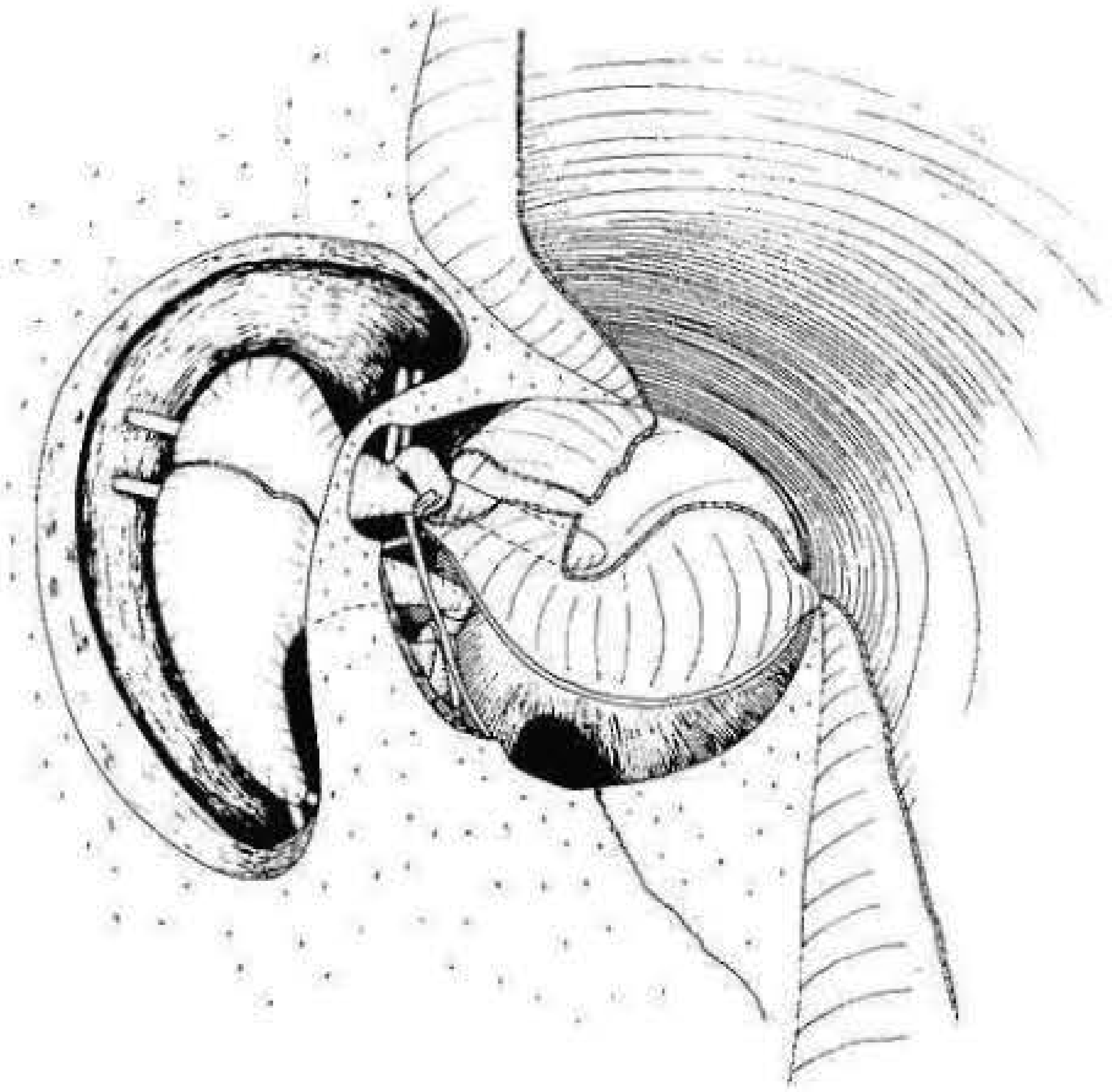


Fig. 1 **Atticotomy with preservation of the bony bridge** in a case of intact ossicular chain. The posterior and superior tympanomeatal flaps are elevated, and superior and posterior tympanotomies are performed, exposing the tympanic cavity. The lateral wall of the attic is removed nearly up to the tegmen tympani. The superior ligaments of the incus and malleus, the posterior ligament of the incus, and the anterior ligament of the malleus are illustrated. In the tympanic cavity, the round window niche, the stapes with the stapedial muscle tendon, and the pyramidal process are illustrated. The posterior malleolar ligament is torn (short arrow)

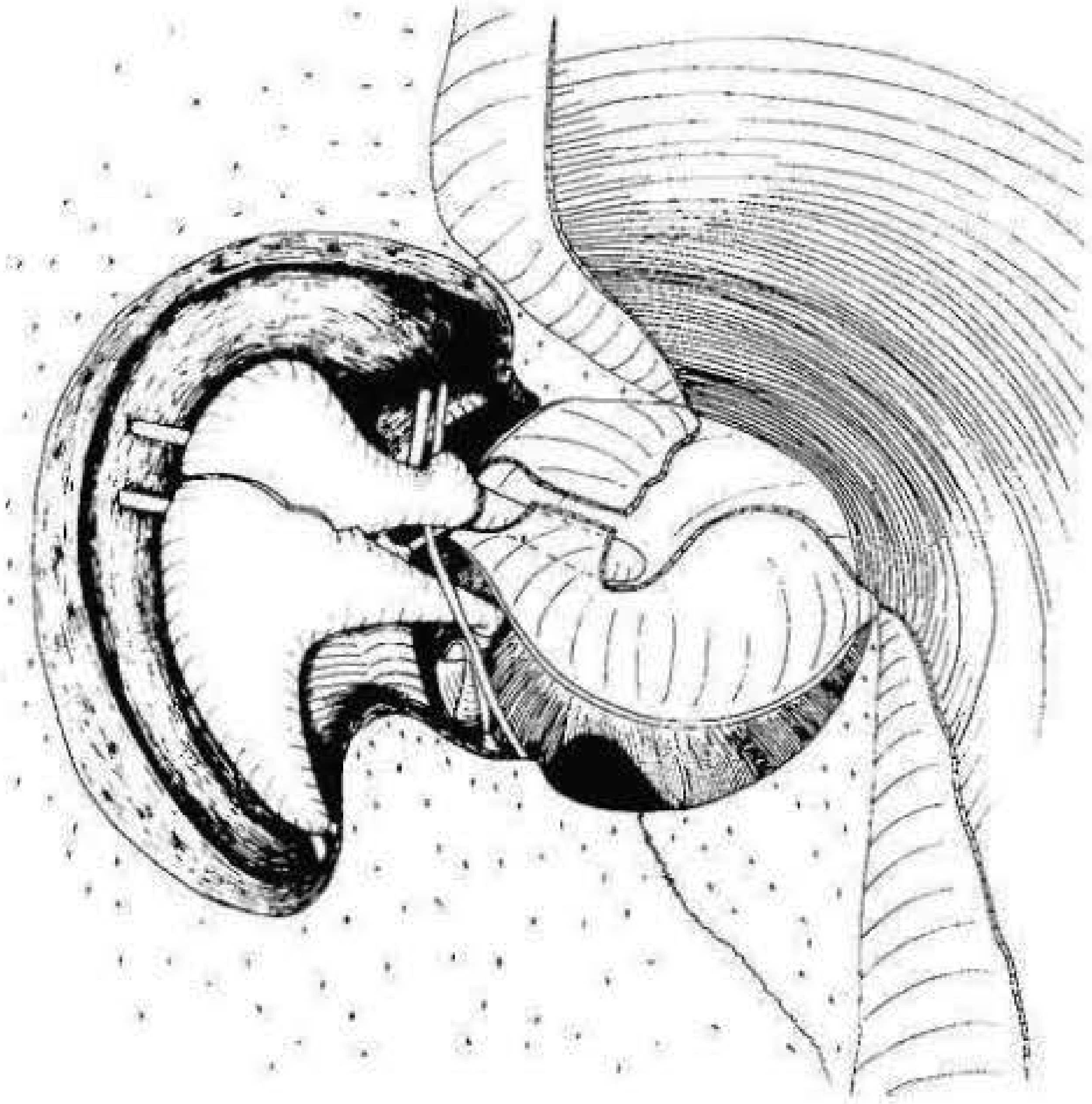


Fig. 2 **Atticotomy with total removal of the bony bridge** in a case with an intact ossicular chain. The posterior and superior tympanotomies are performed, and the bony bridge and lateral wall of the attic are removed, exposing the entire lateral attic. The entire course of the chorda tympani, from the chordal eminence posteriorly under the malleus handle and along the tendon of the tensor tympani muscle to the anterior wall of the attic, is illustrated

ossicles, the atticotomy can be further extended and the medial attic exposed (Fig. **3**).

- Partial removal of the bony bridge. This situation can be caused by spontaneous resorption of the bony annulus by cholesteatoma; or by drilling in cases in which there are difficulties in removing cholesteatoma at a particular point; or, lastly, in cases with bony fixation of the malleus. The bridge can be removed or resorbed in the middle (Fig. **4**), in the anterior part (Fig. **5**), and in the posterior part (Fig. **6**). In attic cholesteatoma there is often resorption of the bone in the region of Shrapnell's membrane (the scutum), and the bridge cannot remain intact in its middle or anterior part. In sinus cholesteatoma, starting with a posterosuperior retraction of the pars tensa, the posterior part of the bridge can be resorbed, or may have to be removed in order to gain better access to this region.

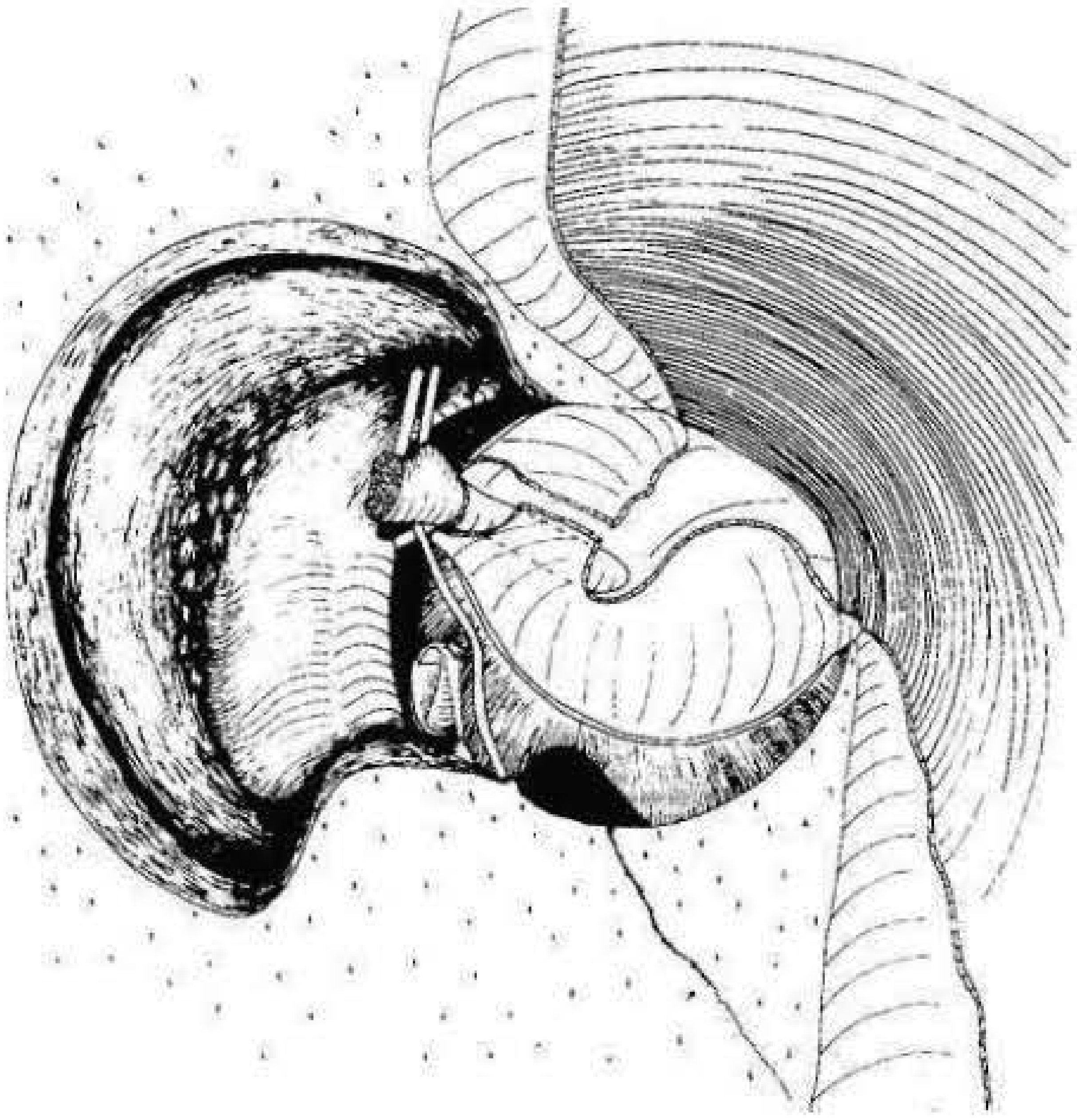


Fig. **3** **Atticotomy with removal of the bony bridge** in a case of resorbed malleus head and incus body, which are removed, leaving only the malleus handle. The medial attic is exposed, illustrating the eminence of the tensor tympani muscle (arrow) with the cochleariform process, the prominence of the horizontal part of the facial nerve, and the lateral semicircular canal. Small perilabyrinthine air cells are indicated

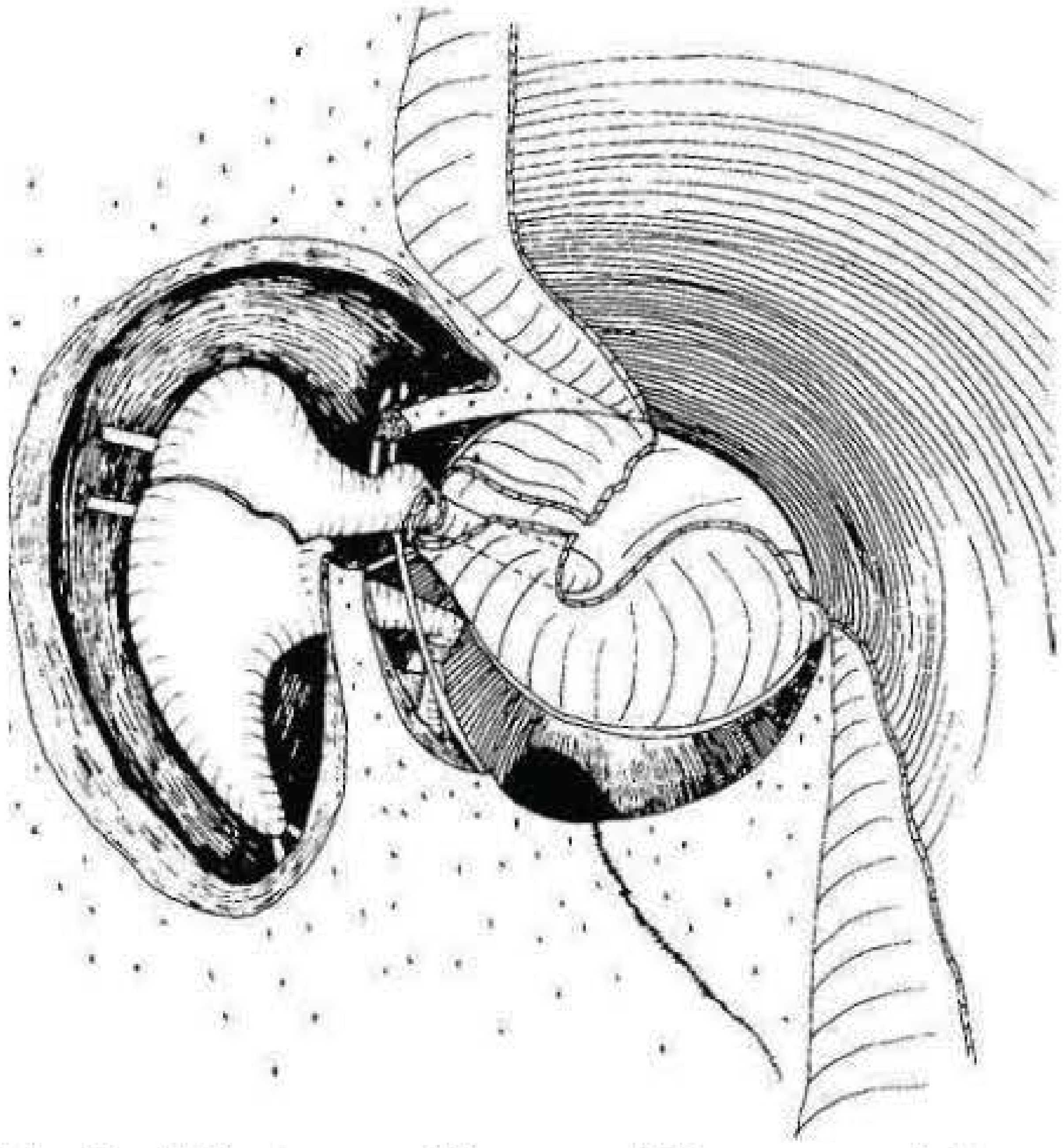


Fig. **4** **Atticotomy with a partially removed bony bridge.** The bridge is either drilled away or resorbed at its middle part—which is a very common situation in attic cholesteatoma

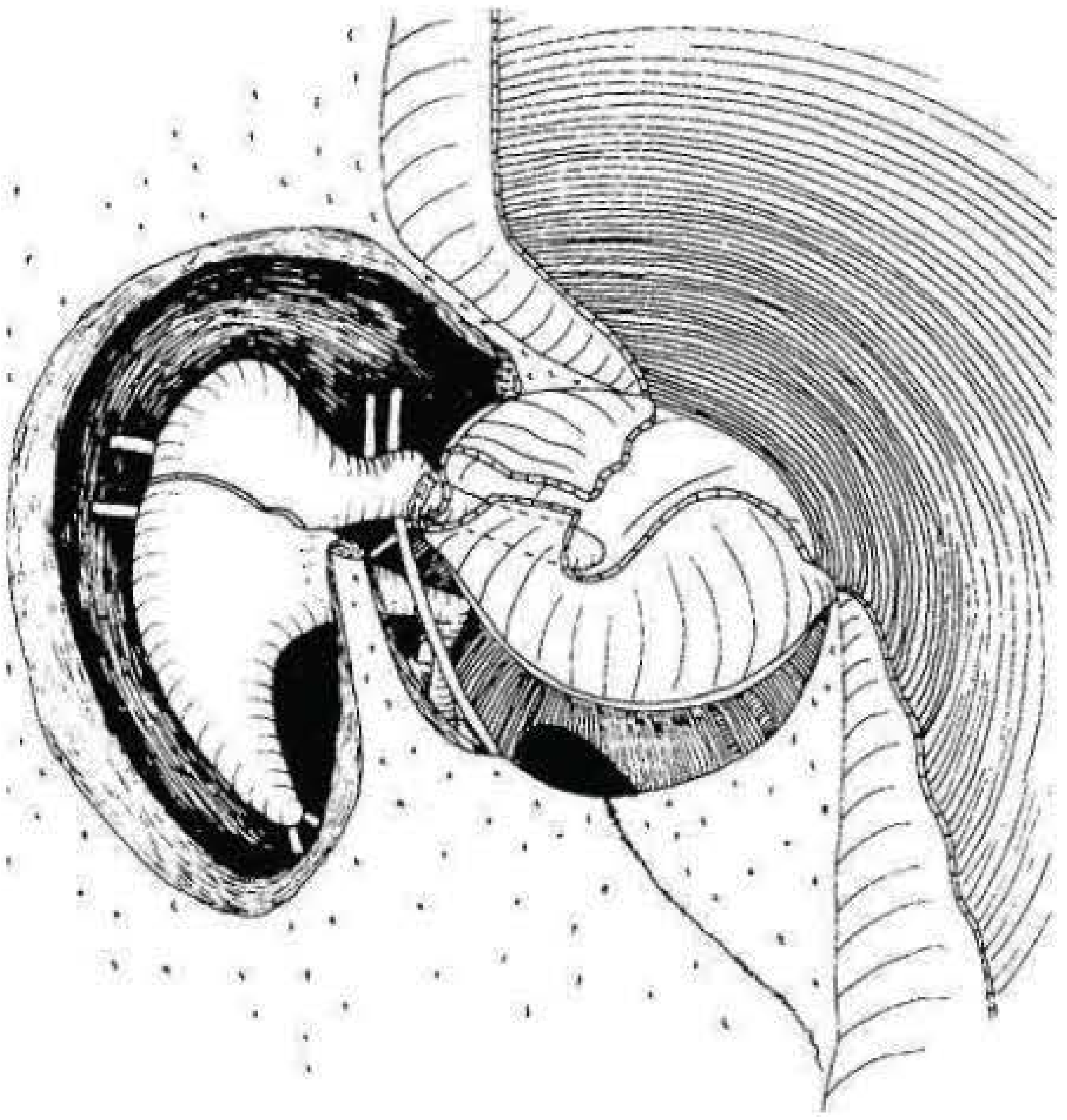


Fig. **5** **Atticotomy with removal of the anterior part of the bony bridge,** sometimes necessary in cholesteatoma extending into the anterior attic

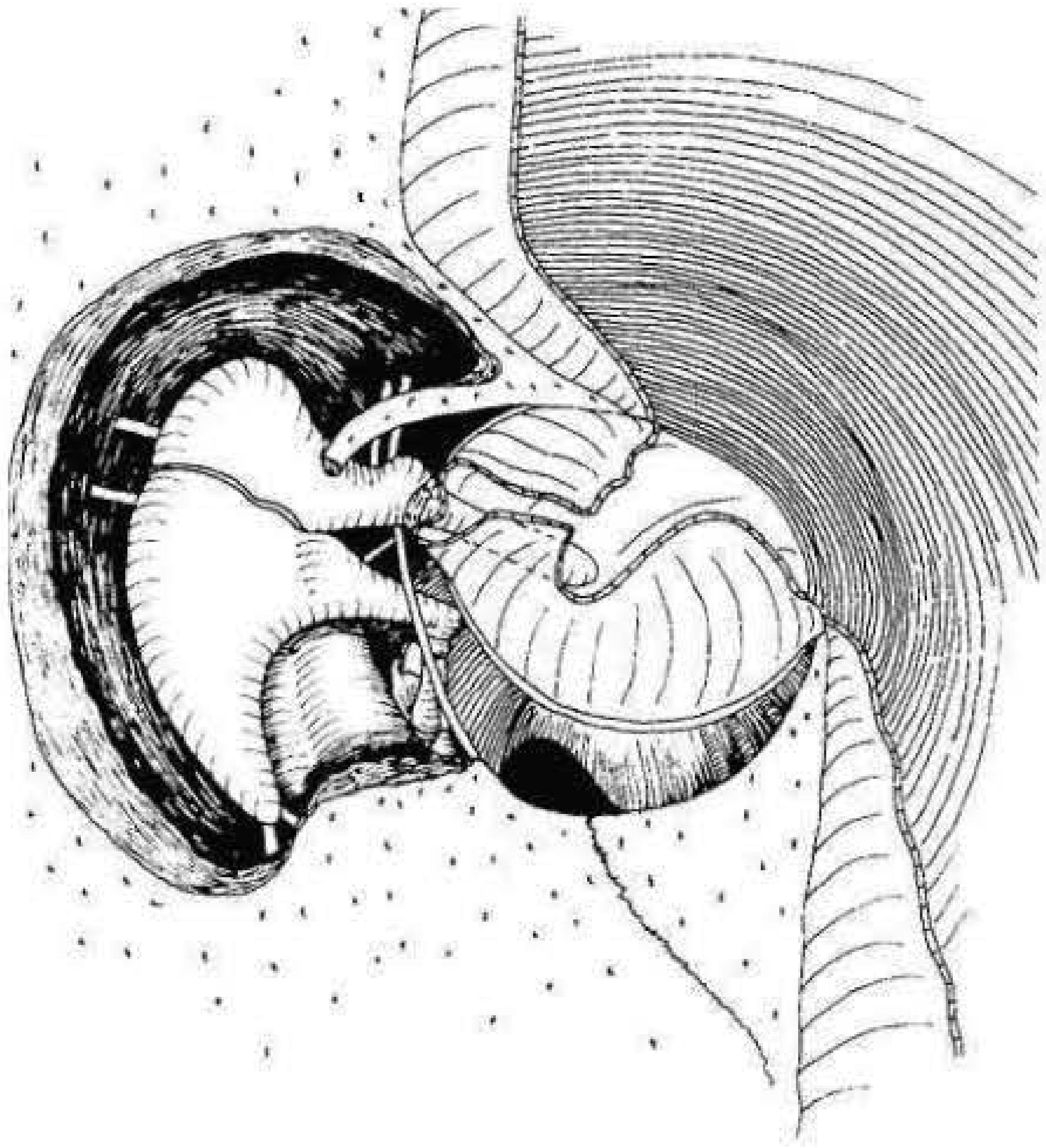


Fig. 6 **Atticotomy with removal of the posterior part of the bony bridge**, sometimes necessary in sinus cholesteatoma

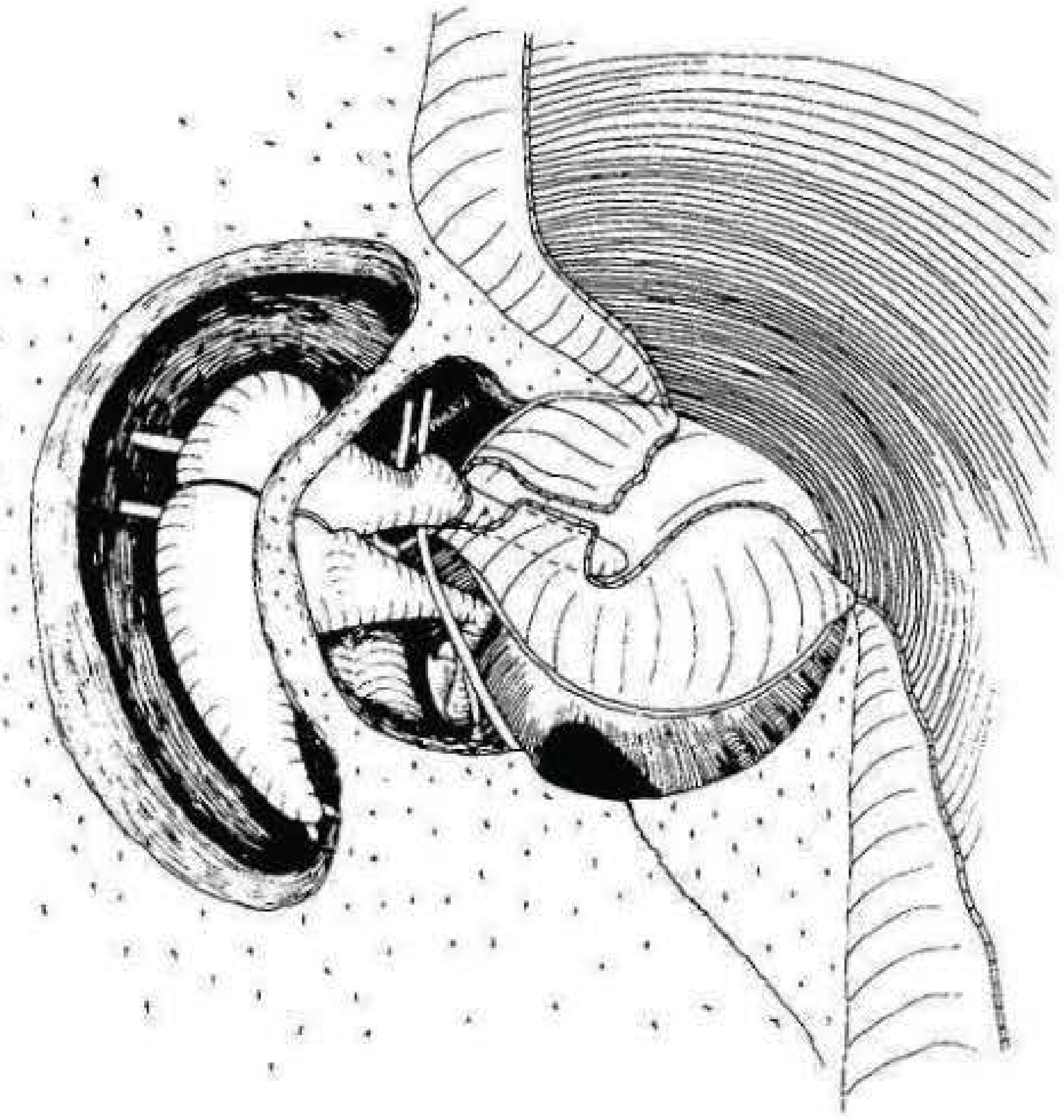


Fig. 7 **Atticotomy with superolateral displacement of an intact bridge**. First some of the bony bridge is drilled away in order to visualize the mesotympanum. An atticotomy with preservation of the bridge is then performed, resulting in a superolateral displacement of the bridge

- Displacement of the intact bridge (Fig. **7**). In cases with attic cholesteatoma and spontaneous resorption of the bridge, or in cases requiring drilling of the bony annulus in order to provide better exposure of the mesotympanum, part of the superior bony annulus (the scutum) is drilled away, displacing it superiorly. After the atticotomy, the new bridge is positioned more superolaterally than the original bridge. This type of displacement of the bridge occurs after performing an anterior atticotympanotomy in order to remove the tensor tympani fold and the bony plate in the anterior attic to improve the ventilation through it (Morimitsu 1991, Rosborg 1993).

The present author prefers atticotomy with preservation of the bridge, but the methods involving removal of the bridge have been quite popular, mainly because they are less time-consuming and are easy to perform. There are many possible combinations of the methods of partial removal of the bony bridge and displacement of the bridge, resulting in great variability in atticotomy.

Atticoantrotomy

Atticoantrotomy is an extension of the atticotomy in a posterior direction through the transmeatal route. The lateral attic and aditus walls are removed, and the antrum is entered. The posterosuperior bony ear canal wall is removed, and the access to the antrum is gradually widened (Figs. **8, 9**).

An atticoantrotomy can be performed through the transcortical route, but is usually performed through the transmeatal route. There is a gradual transition from an atticotomy to the conservative radical mastoidectomy, and in fact there are no rules as to when an extensive atticoantrotomy should be described as a conservative radical operation or as an atticoantrotomy (Fig. **8**).

In cases with poor pneumatization, a small antrum, and a sclerotic mastoid process, an atticoantrotomy results in a small cavity with smooth walls (Fig. **9**). In a large cell system, the atticoantrotomy results in a large cavity.

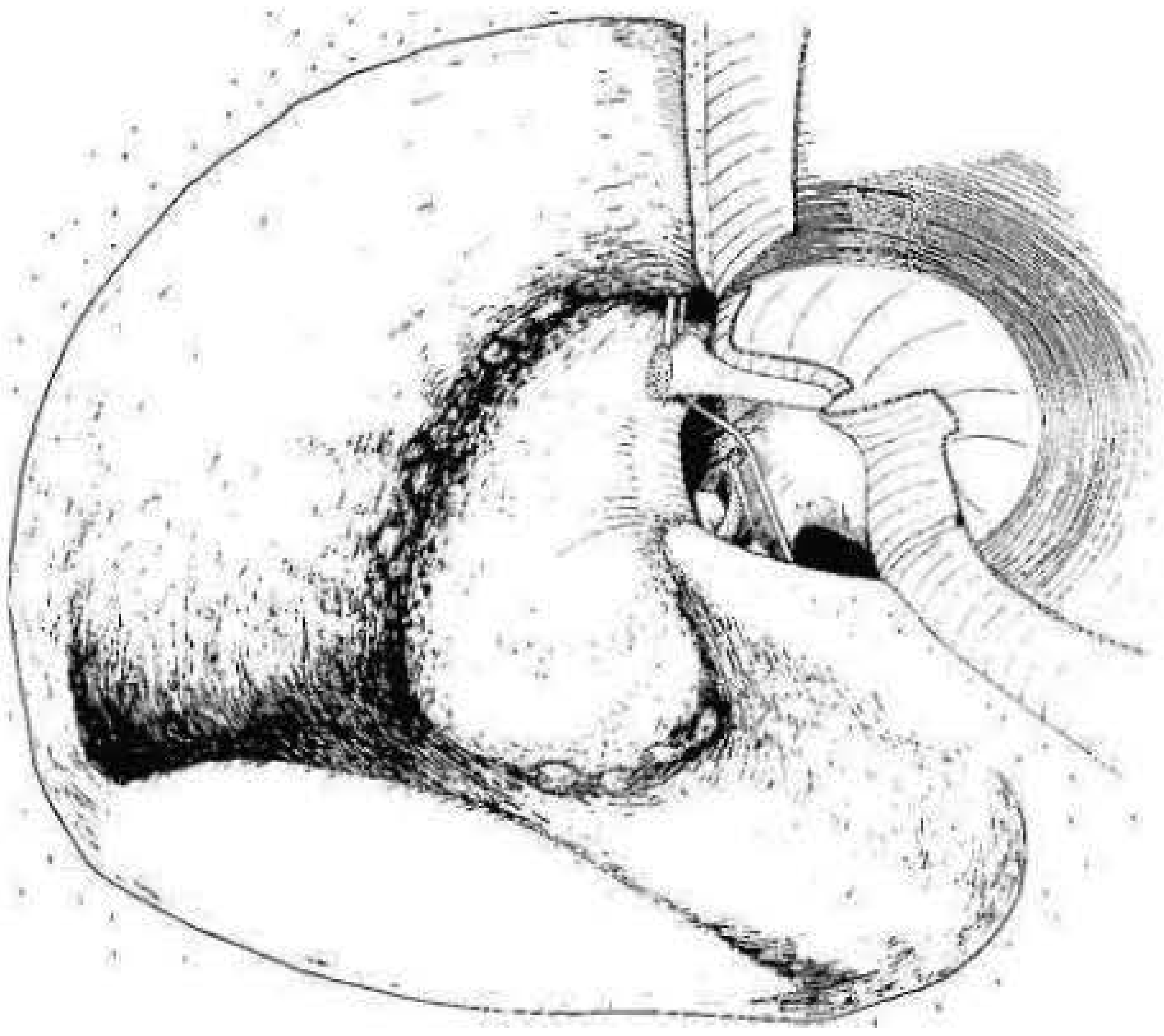


Fig. **8** **The large atticoantrotomy.** The posterosuperior bony wall of the external auditory canal is removed, and the tegmen tympani, tegmen antri, and tegmen mastoidei, as well as the prominence of the sigmoid sinus, are exposed, leaving thin, smooth, bony plates. The sinodural angle is cleansed, and the walls are smoothed. The sinus-facial angle is relatively deep, and the facial ridge is high. The malleus head and incus are removed, exposing the medial walls of the attic and aditus ad antrum, with the lateral semicircular canal and the eminence of the horizontal part of the facial nerve. In the anterior attic, the anterior malleolar ligament and chorda tympani are present. Some flat perilabyrinthine air cells superior to the lateral semicircular canal and inferior to the posterior semicircular canal remain

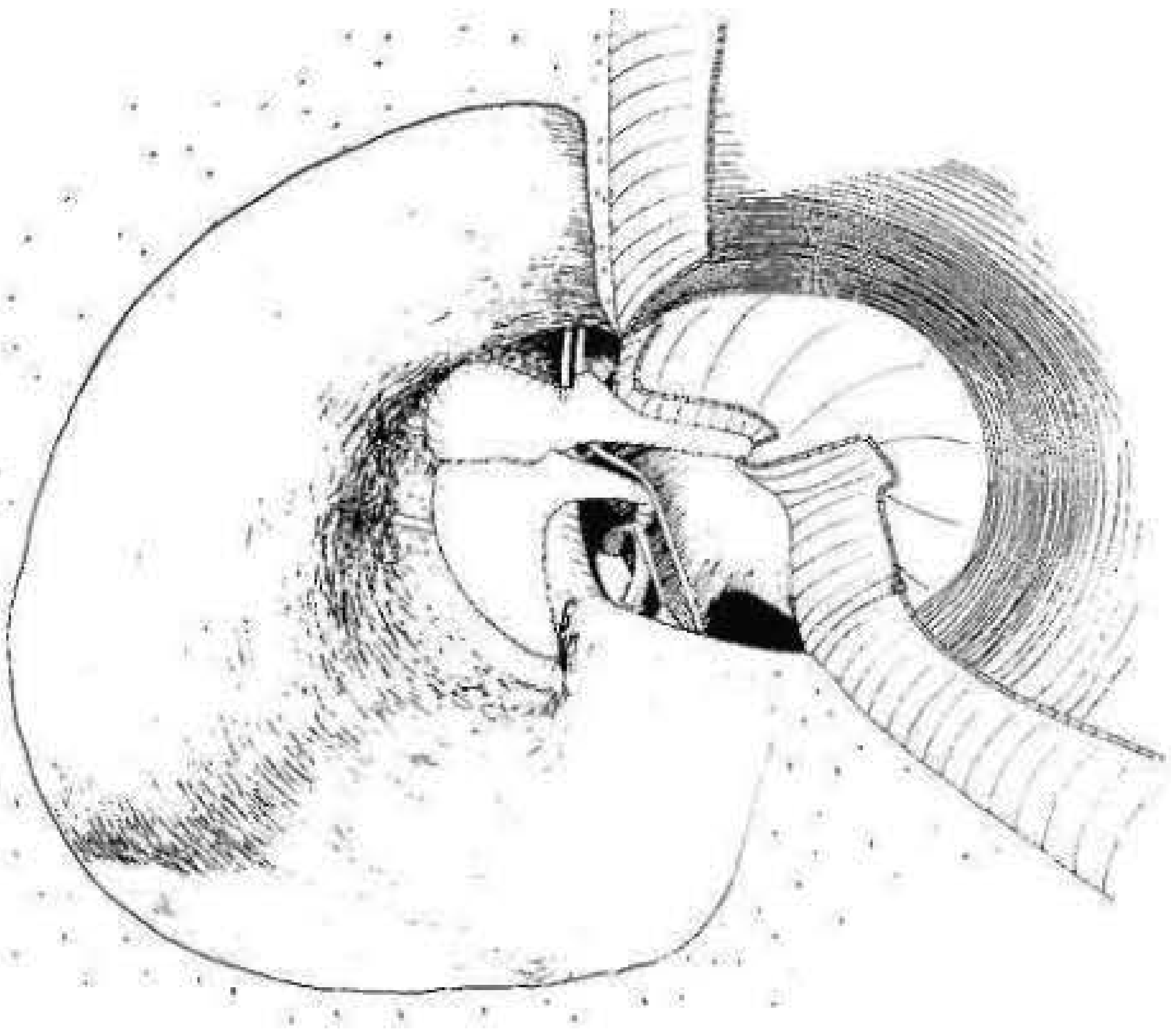


Fig. **9** **A small atticoantrotomy** in a case of sclerotic mastoid process, small antrum, and intact ossicular chain. The cavity is small, with smooth walls, the sinodural angle is flat, and the sinus–faciai angle is small. There is a smooth transition from the facial ridge to the eminence of the horizontal part of the facial nerve.

Bondy's Operation

An atticoantrotomy is described as Bondy's operation if the tympanic cavity is not entered (Bondy 1910). The lateral part of the cholesteatoma matrix is removed (Fig. **10**) and the medial part is left in place (Fig. **11**), marsupializing the cholesteatoma. If the tympanic cavity is entered (Fig. **12**), the operation is not described as Bondy's operation, but as an atticoantrotomy or conservative radical operation, even if the cholesteatoma matrix is left in place (Fig. **13**).

If the tympanic cavity is opened and the cholesteatoma marsupialized with the matrix being left in place in the attic, fascia has to be placed under the matrix in order to prevent ingrowth of the cholesteatoma into the tympanic cavity, and also to allow safe adaptation between the keratinized squamous epithelium of the matrix and the epithelium of the replaced drum remnant and canal skin (Fig. **14**).

The principal difference between Bondy's operation and atticoantrotomy or conservative radical surgery with marsupialization of the cholesteatoma is therefore the opening of the tympanic cavity.

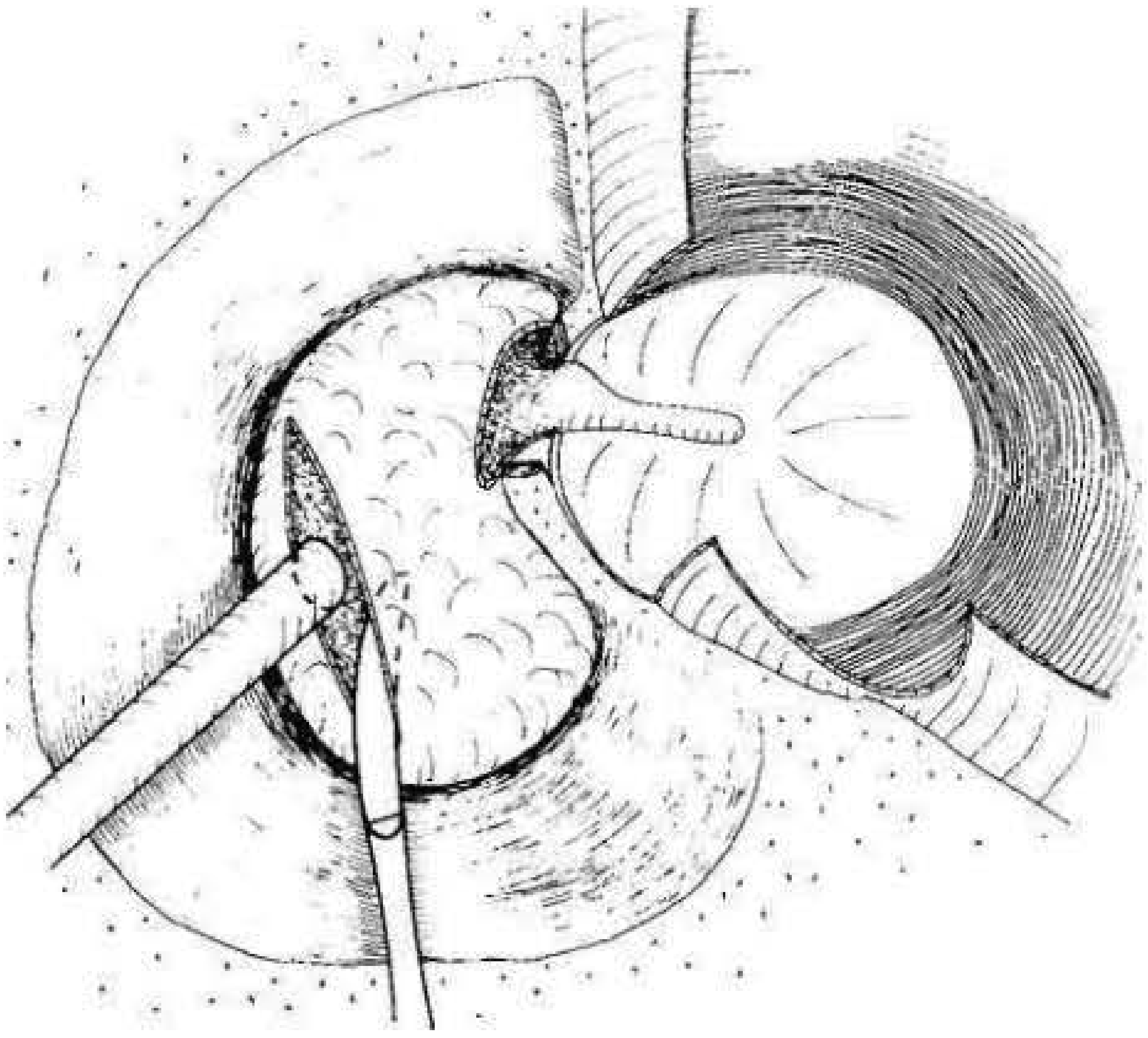


Fig. **10** **Bondy's operation.** After atticoantrotomy with removal of the posterosuperior bony meatal wall, the cholesteatoma sac involving the atticus and antrum is exposed. The sac is incised, a suction tube is placed in the sac, and the cholesteatoma mass is sucked away. The lateral part of the matrix is cut off. The tympanic cavity is *not* entered

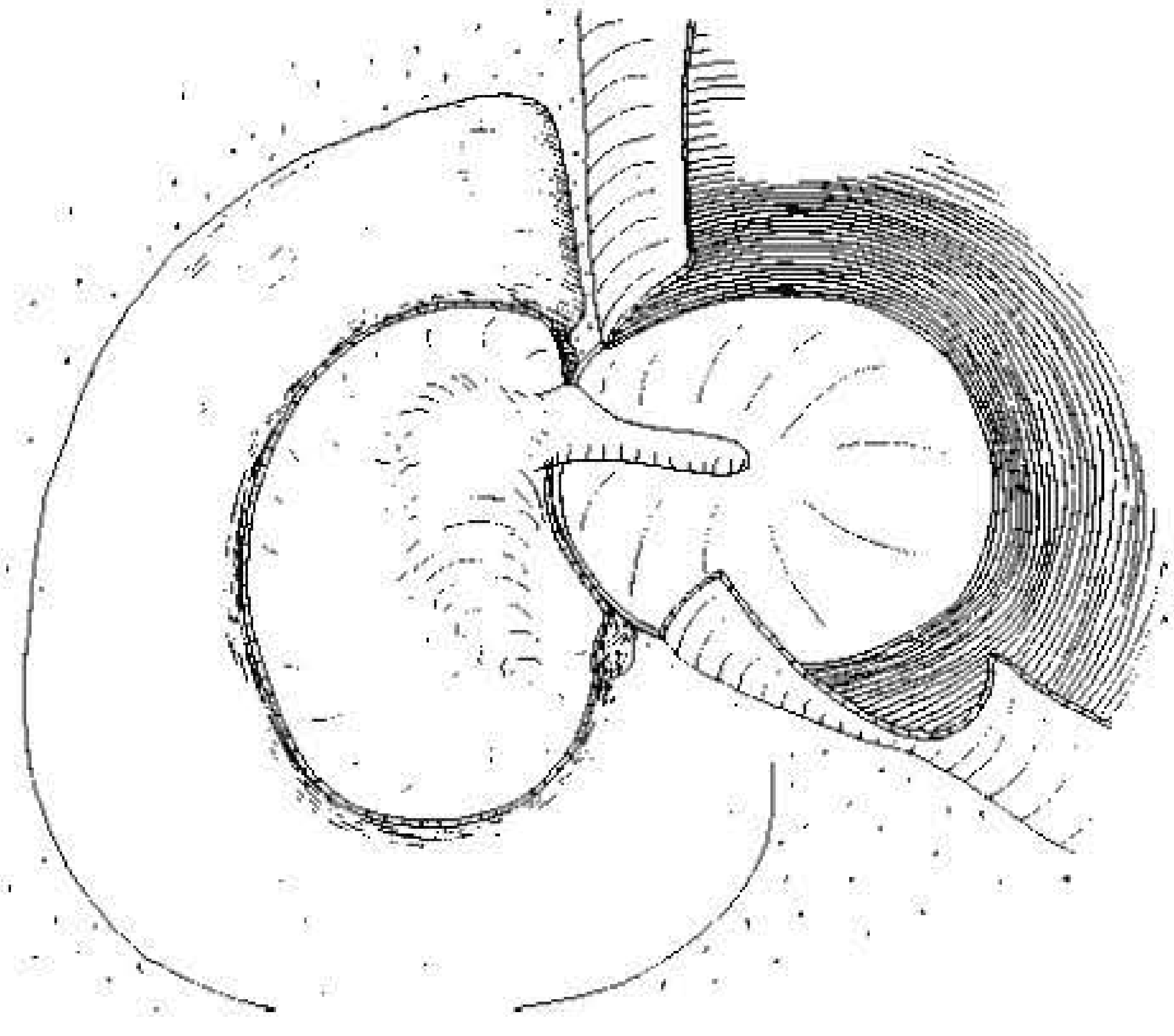


Fig. **11** The completed Bondy's operation, with the atticoantrotomy. The medial part of the cholesteatoma matrix is left in place, and the bridge is removed, exposing all the cholesteatoma matrix. The malleus and incus are intact, but covered with the cholesteatoma matrix. Superiorly, the epithelial flap will be returned to cover the superior wall of the cavity. Inferiorly, the flap will cover the facial ridge. The smooth walls of the cavity will soon be epithelialized

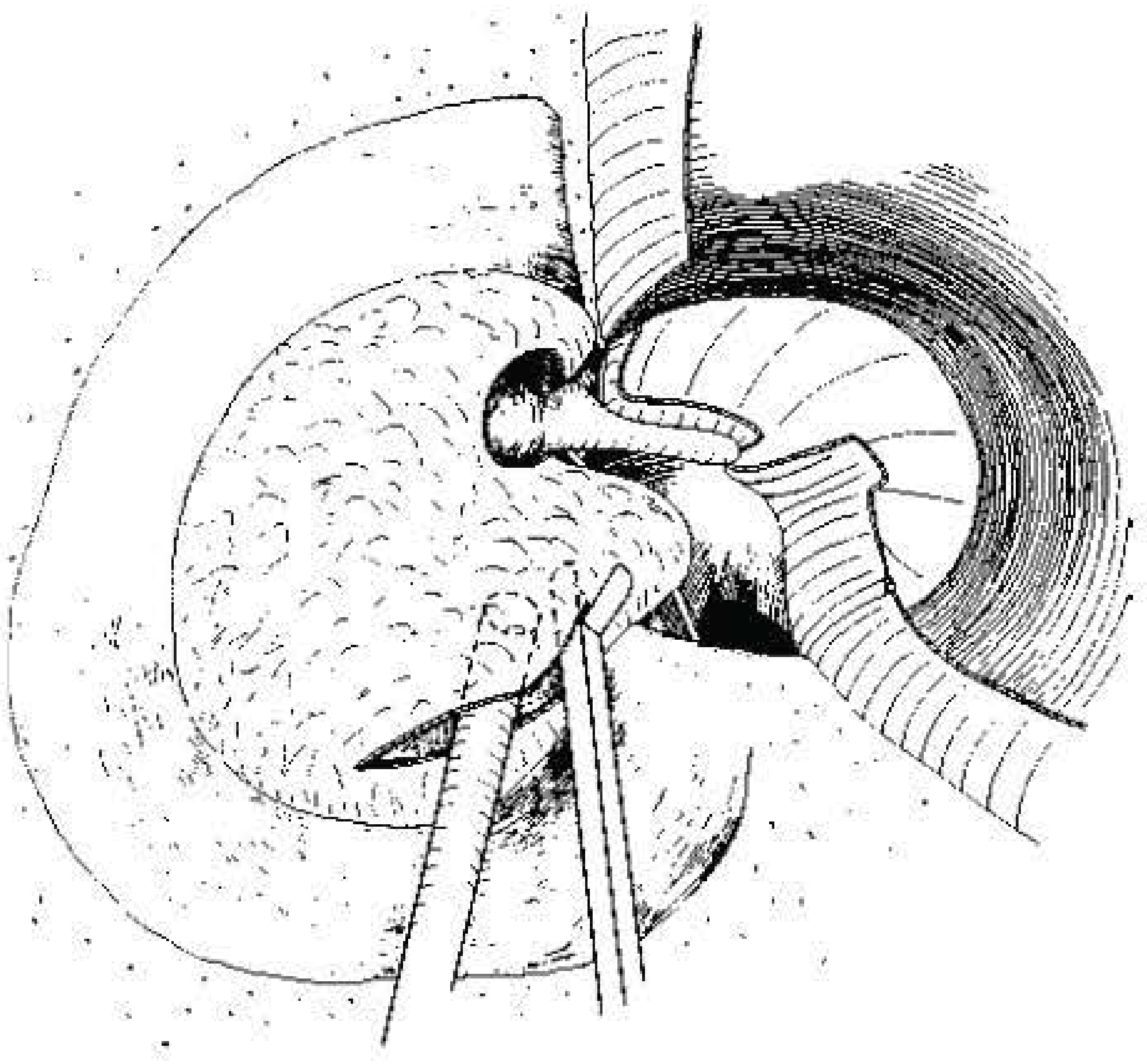


Fig. **12** **Atticoantrotomy, or conservative radical operation,** with marsupialization of an attic cholesteatoma extending into the tympanic cavity, which is open. The sac is incised, and the cholesteatoma is sucked out. The tympanic cavity is entered, with the tympanomeatal flap being elevated posteriorly

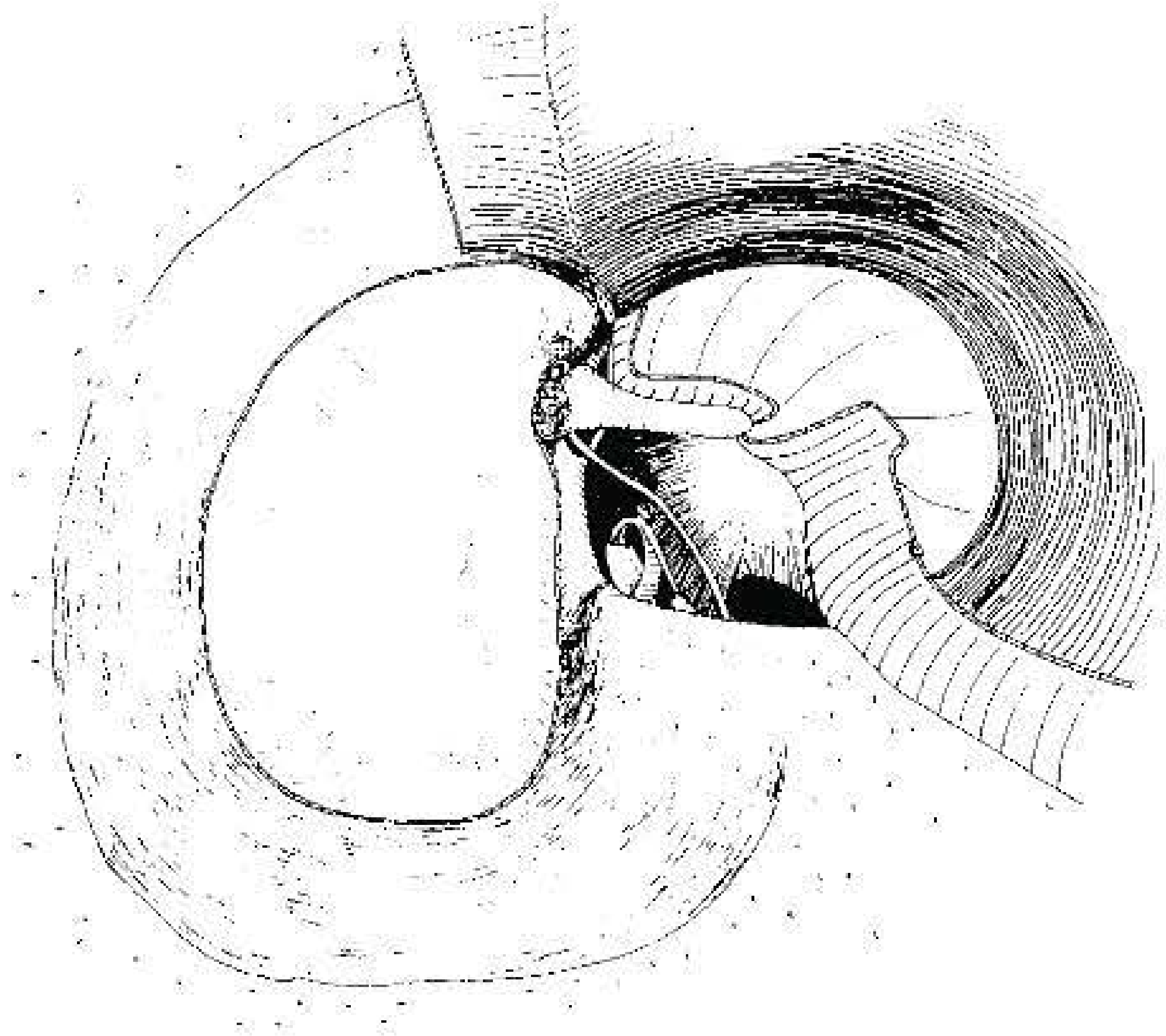


Fig. **13** After removal of the partly eroded incus, and after resection of the head of the malleus, the medial part of the cholesteatoma matrix is left in place. The cholesteatoma is marsupialized in the attic and antrum regions, but removed from the tympanic cavity

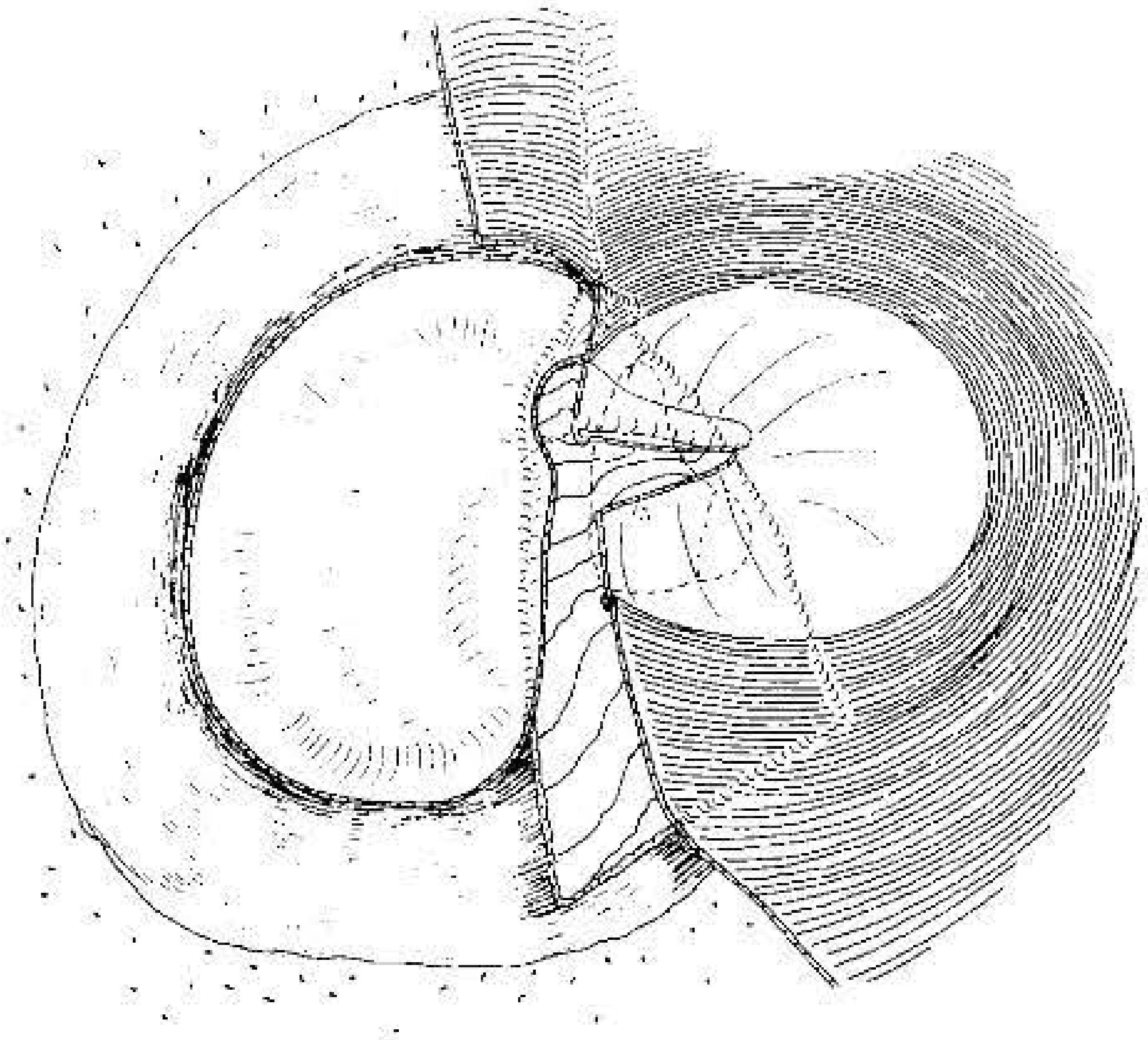


Fig. **14** After an incus interposition between the stapes and the malleus handle, after placement of the fascia under the epithelial edges and under the drum, and after replacement of the skin flaps, the conservative radical operation is completed

If there is no need for hearing improvement and ossiculoplasty, the tympanic cavity is not opened in Bondy's operation, is contrast to atticoantrotomy with marsupialization, where a tympanoplasty is also performed, either to prevent ingrowth of the cholesteatoma into the tympanic cavity or as part of an ossiculoplasty (Fig. **14**).

In the treatment of attic cholesteatoma, a gradual transition from an atticotomy with removal of the bony bridge (Fig. **3**) to Bondy's operation can be seen. Usually, it is only the extent of bone removal from the posterosuperior ear canal wall and the adherence of the cholesteatoma membrane to the lateral semicircular canal, with blockage of the ventilation through the tympanic isthmus, that distinguishes a large atticotomy from a small Bondy's operation. In both types, the medial part of the cholesteatoma sac is left in place, covering the intact ossicular chain (Figs. **15, 16**), or the medial wall of the aditus ad antrum with the lateral semicircular canal (Fig. **17**) and the medial wall of the antrum (Fig. **18**). These techniques are fast, safe, and simple, and can easily be performed under local anesthesia.

In cases with a small attic cholesteatoma, good hearing, and no significant discharge, and in which the bottom of the cholesteatoma or a deep retraction pocket cannot be seen, an atticotomy can be performed by removing the scutum until the bottom is visible (Figs. **15, 19**). The lateral wall of the cholesteatoma sac is removed, and the medial wall is left in place, improving access to the cholesteatoma sac and facilitating migration of the keratin from the sac.

In an attic cholesteatoma involving the aditus ad antrum, a large part of the posterosuperior bony ear canal has to be drilled in order to perform a large atticotomy and marsupialize the cholesteatoma (Figs. **16, 20**). Ventilation of the antrum still occurs through the tympanic isthmus under the incus body and the malleus head, and under the medial part of the cholesteatoma matrix, which is not yet adherent to the lateral semicircular canal (Fig. **16**). The adherence of cholesteatoma membrane to the lateral semicircular canal is probably the most reliable sign differentiating the atticotomy from the Bondy's operation in cases of attic cholesteatoma. In cases with adherence of the cholesteatoma membrane to the lateral semicircular canal (Fig. **17**), the aditus ad antrum is involved in the cholesteatoma, and ventilation of the antrum cannot take place through the tympanic isthmus. Extensive removal of bone is necessary to visualize the cholesteatoma sac, and the result resembles a small open atticoantrotomy cavity—a Bondy's operation (Figs. **11, 17**). Similarly, in cases with involvement of the antrum (Fig. **14**), a Bondy's operation is performed, resulting in a small open cavity.

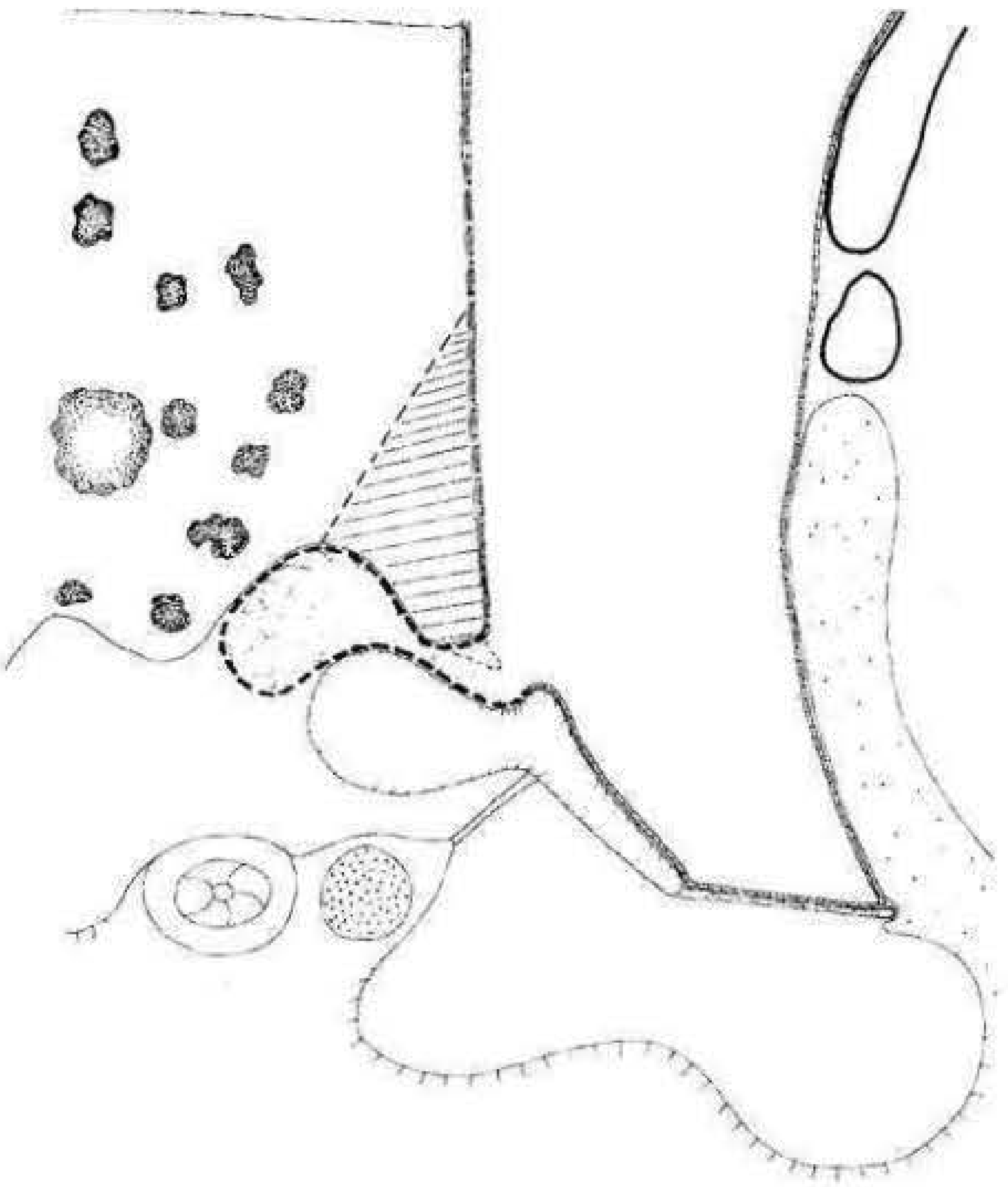


Fig. **15** **Side view of an atticotomy with removal of the scutum and the bony bridge** (hatched area) in a case of small attic cholesteatoma located in the lateral attic between the head of the malleus and the scutum (thick dashed line). The lateral membrane of the cholesteatoma sac is removed exposing its medial wall. The antrum is aerated from the mesotympanum through the tympanic isthmus

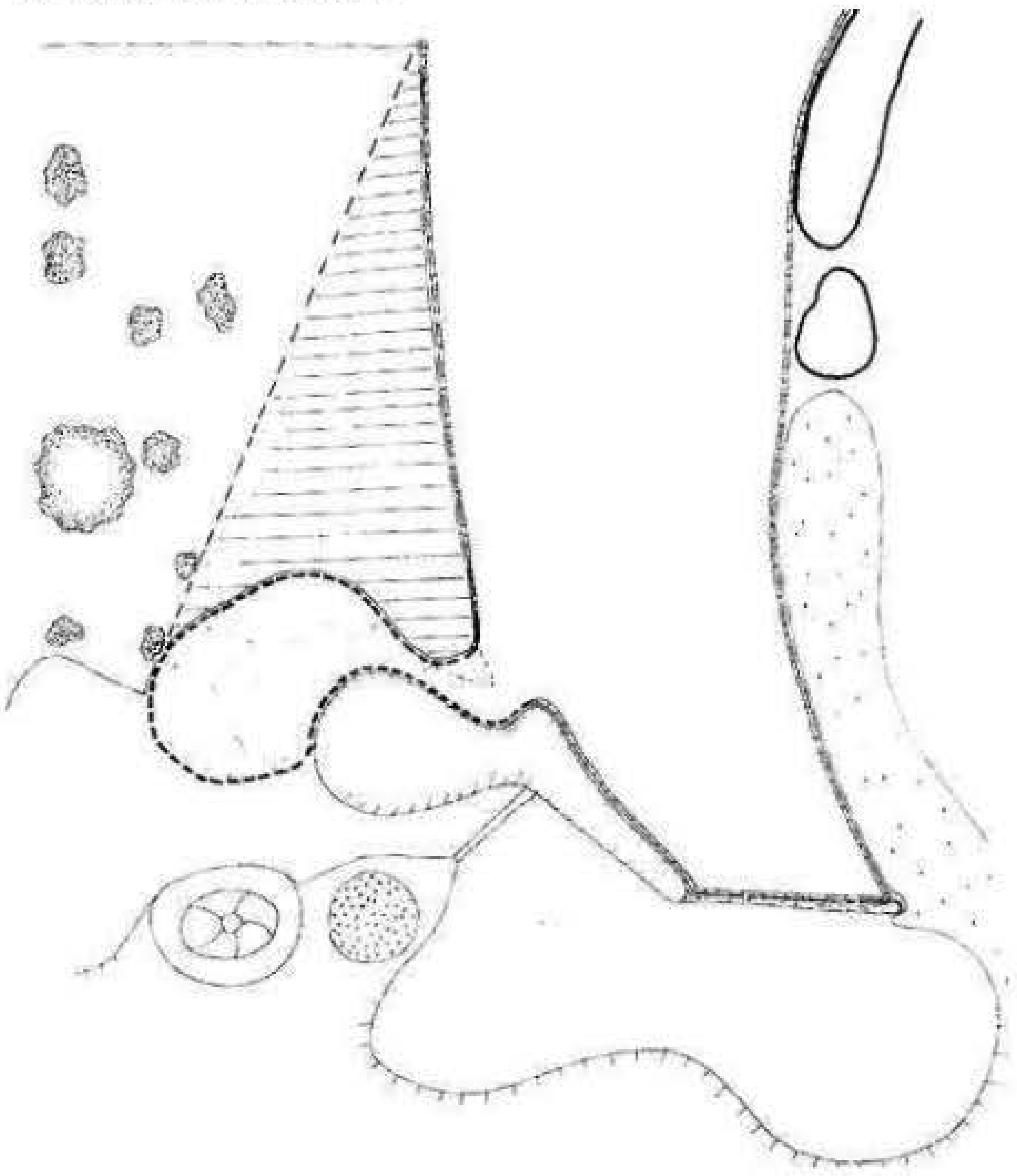


Fig. **16** **Side view of an atticotomy with large removal of the superior bony ear canal wall** (hatched area) and the lateral part of the cholesteatoma in order to marsupialize the attic cholesteatoma (dotted line). Ventilation of the antrum through the tympanic isthmus is still possible

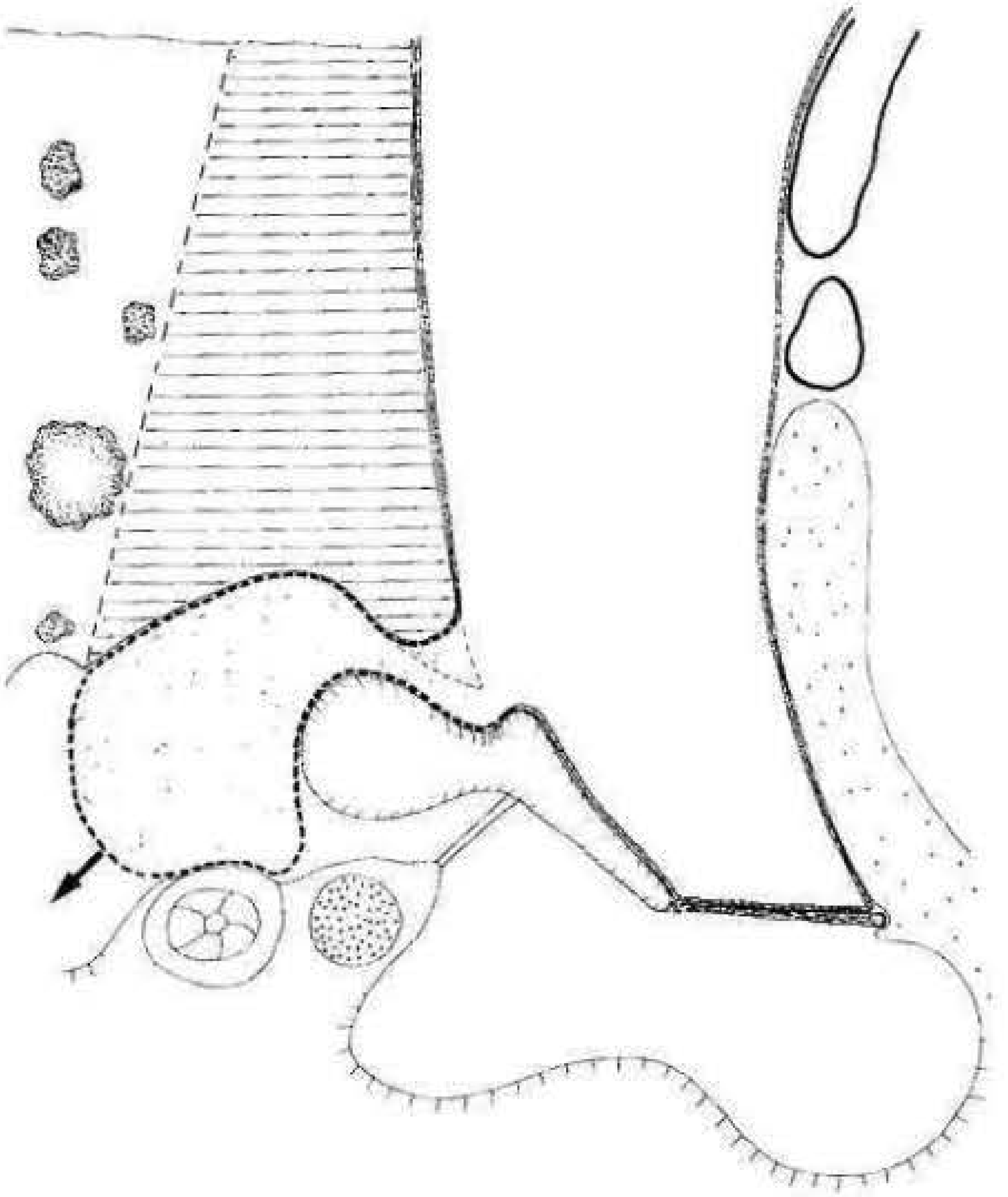


Fig. **17** **Side view of a large atticotomy or a small Bondy's operation** in an attic cholesteatoma involving the aditus ad antrum, adherent to the lateral semicircular canal closing the tympanic isthmus, and blocking the ventilation of the antrum. Even after removal of the large part of the superior bony ear canal wall (hatched area) and the lateral membrane of the cholesteatoma sac (dashed line) with good exposure of the medial cholesteatoma wall, progression of the cholesteatoma is possible towards the antrum (arrow)

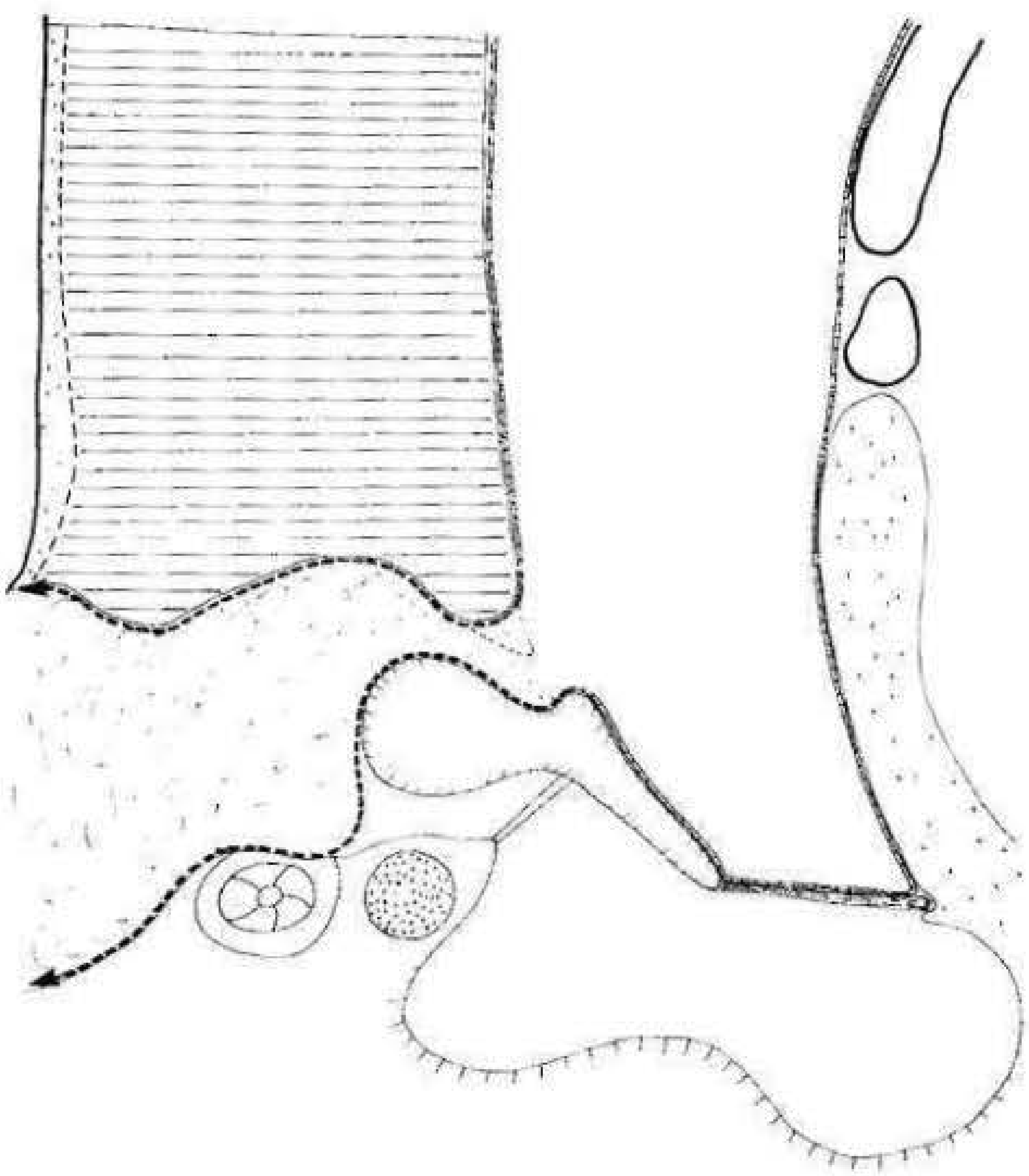


Fig. **18** **Side view of a Bondy's operation** in a case with large attic cholesteatoma. All bone from the posterosuperior canal wall up to the middle fossa dura plate is removed (hatched area), together with the lateral membrane of the cholesteatoma sac (dashed line). The cholesteatoma is marsupialized, with wide access to the small open cavity. The ossicular chain is intact, and the medial cholesteatoma membrane is adherent to the medial aditus and antrum walls

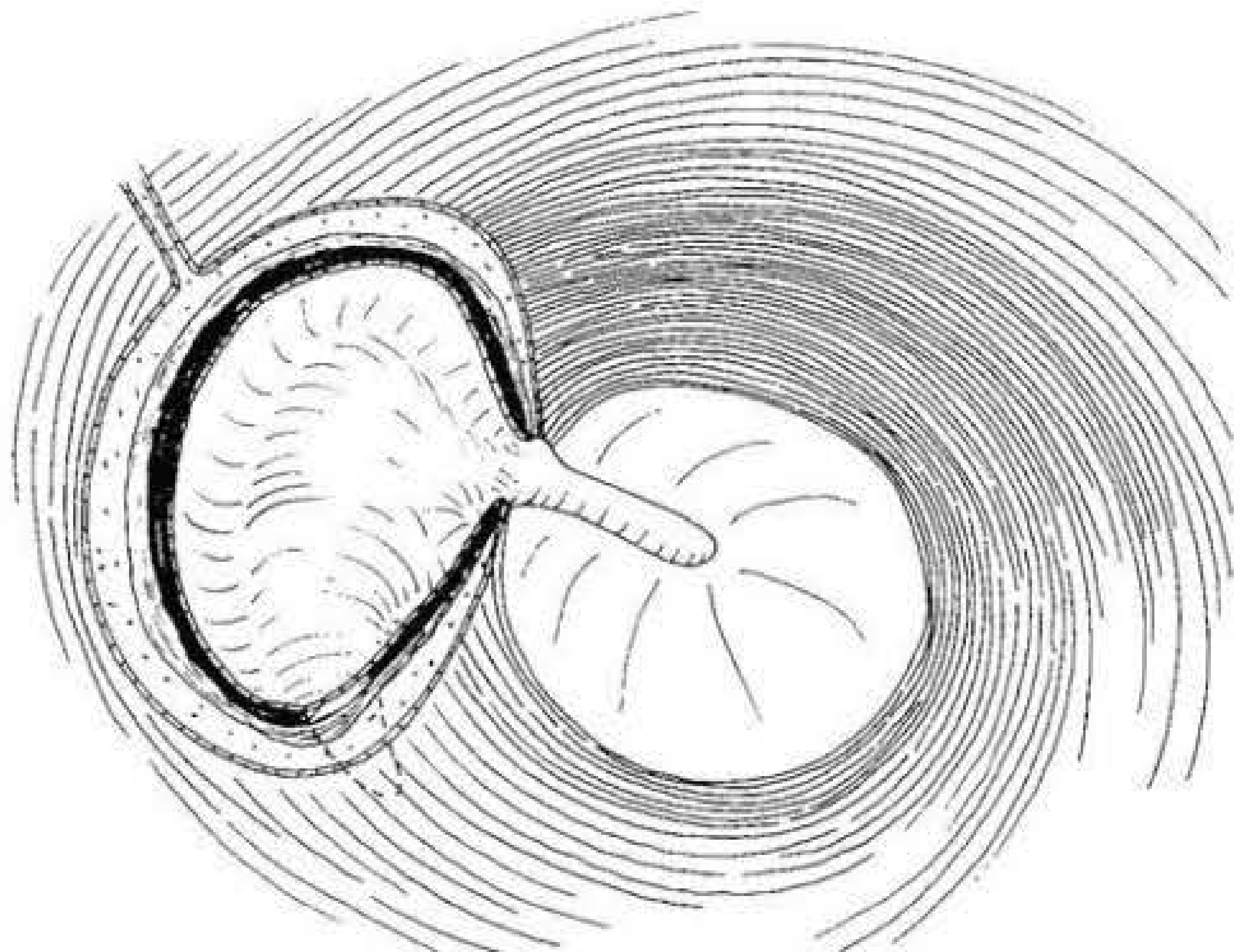
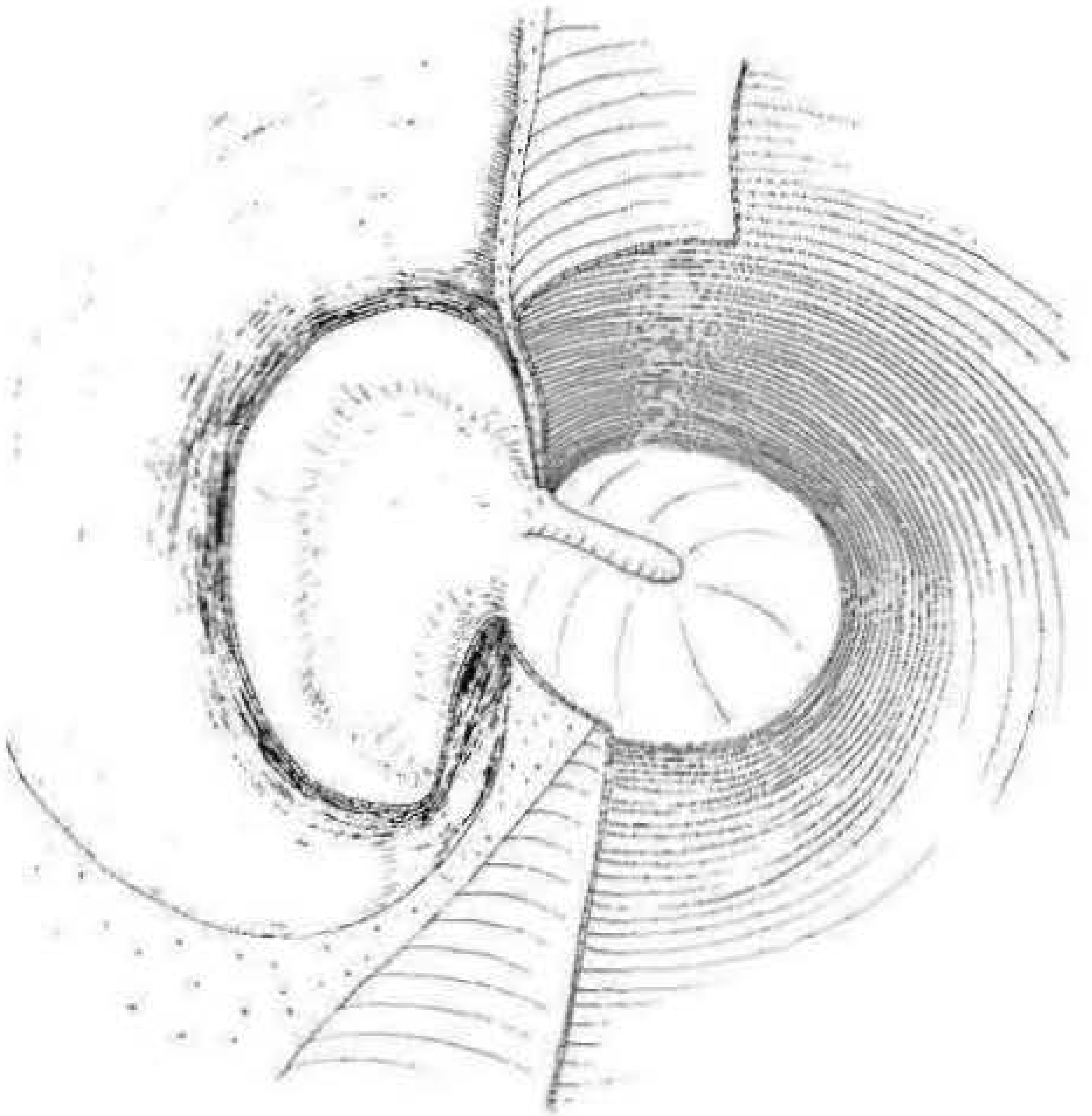


Fig. **19** **Atticotomy with removal of a small part of the bony bridge**, marsupializing a small attic cholesteatoma. Its medial membrane continues from the Shrapnell's membrane region and covers the malleus head and incus body. The tympanic cavity is not entered, and the exposed bone will soon be covered with the ear canal skin

Fig. 20 **Large atticotomy with removal of the bony bridge** in an attic cholesteatoma. Extensive drilling of the superior ear canal wall is performed, and the cholesteatoma is marsupialized. The medial wall of the cholesteatoma sac covers the head of the malleus and the body of the incus. The cholesteatoma is not adherent to the lateral wall of the semicircular canal, providing good ventilation of the antrum through the tympanic isthmus. After replacement of the canal skin flaps, the denuded bone will be reepithelialized, providing good migration from the attic region

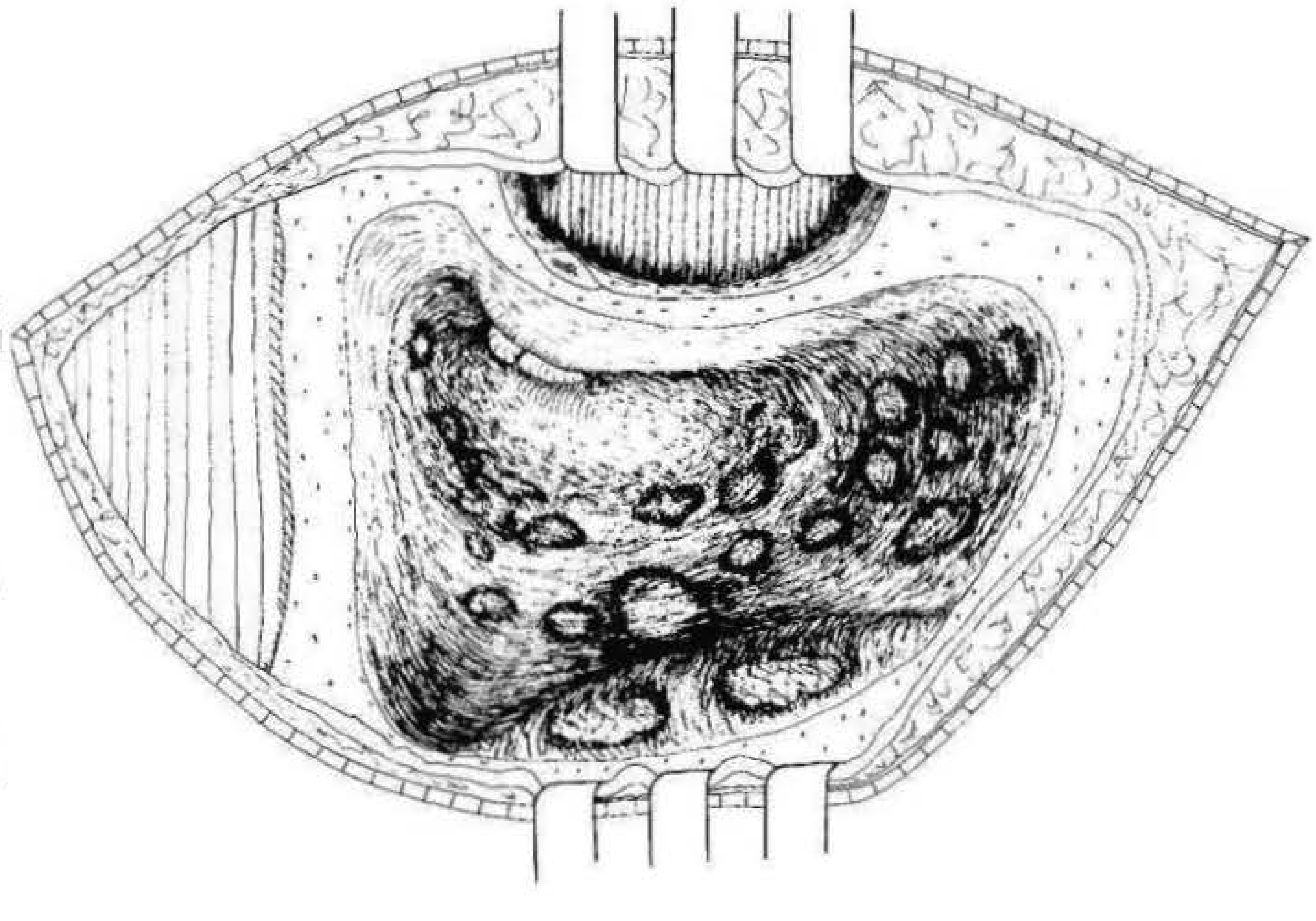


Cortical Mastoidectomy

The cortical mastoidectomy (Schwartze 1873) is a transcortical opening of the mastoid cells and the antrum. It is the initial stage of any transmastoid surgery of the middle ear, inner ear, facial nerve, endolymphatic sac, labyrinth, internal auditory canal, and various procedures on the skull base for removing skull base tumors. The extent of the mastoidectomy depends on the main operation and the access it requires.

The term *simple mastoidectomy* is usually used for drainage of a mastoid abscess. The bony meatal wall remains intact, and is relatively thick medially. The anterior attic in simple mastoidectomy is not exposed, and only the superior aspects of the malleus head and incus body, as well as the prominence of the lateral semicircular canal, are visualized. The cavity walls are usually not polished, and the mucosa is widely preserved (Fig. **21**).

Fig. **21** **Simple cortical mastoidectomy in a retroauricular approach**. The antrum and the mastoid cells are opened. The bony meatal wall is intact but thick, because the small cells of the ear canal have not been removed. The lateral semicircular canal, the malleus, and the incus are just visible. The lateral attic wall is not opened, neither nor is the anterior attic. The ear canal skin is elevated only laterally to identify the spine of Henle. The ear canal is not entered from behind



Conservative Radical Operation

Conservative radical mastoidectomy, conservative radical operation, or modified radical operation is a "canal wall–down" procedure, denoting a mastoidectomy with opening of the antrum and attic, removal of the posterosuperior bony canal wall, either drilling away of the bony bridge and lowering of the facial ridge or preserving the thinned-down bony bridge (Dagget 1949). The structures within the tympanic cavity are preserved, hence the term conservative radical operation (Fig. **8**). As mentioned above, there is a gradual transition from the atticoantrotomy to conservative radical operation. The only difference is, in the present author's opinion, the extent of the bone work involved in the mastoid process. In the radical operation, the exenteration of the air cells is more radical than in an atticoantrotomy (Fig. **9**). Also, marsupialization of the cholesteatoma and leaving intact the medial part of the cholesteatoma membrane (Fig. **13**) is not included in conservative radical operation. In contrast to methods involving an intact soft meatal wall, a meatal flap is created both in the conservative and in the classical radical operation.

Classical Radical Operation

Classical radical mastoidectomy, or classical radical operation, is a "canal wall–down" mastoidectomy, and includes the same bone work in the mastoid process as the conservative radical operation. However, the structures within the tympanic cavity are removed, e. g., the remnants of the incus and the malleus, and the drum remnant with the fibrous annulus (Fig. **22**) and sometimes even the bony annulus (Fig. **23**). In a classical radical cavity, closure of the Eustachian tube is performed—this can be done by several techniques, but closure of the tube is not essential for the term "classical radical operation." There are methods of classical radical operation that do not involve closure of the tube. A closure of the tympanic cavity, a myringoplasty, is excluded from this term, but since today the majority of surgeons, including myself, perform reconstruction of the drum despite removal of the fibrous annulus, the classical radical operation as defined above is nowadays seldom performed. Today, even after radical removal of all structures from the tympanic cavity, an attempt to close the tympanic cavity is performed to achieve faster healing, or sometimes even to reventilate the tympanic cavity, or at least a part of it.

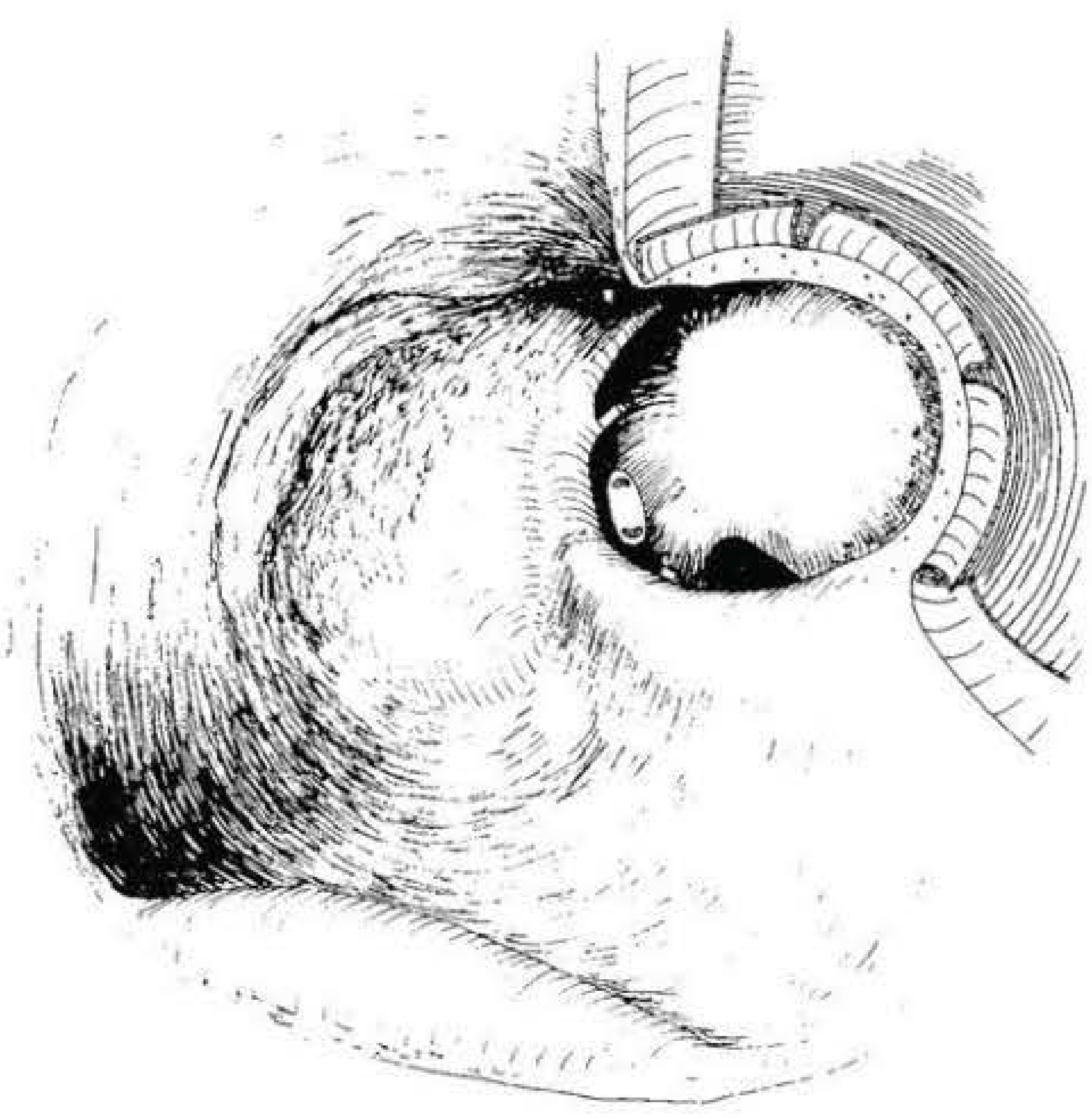


Fig. **22** **Situation in the tympanic cavity after a classical radical mastoidectomy** with removal of the fibrous annulus and all ossicles. The ear canal skin is elevated outward during removal of the fibrous annulus. The septa of the hypotympanic air cells are removed. The cavity is large, the facial ridge is low, and the ossicles are exteriorized

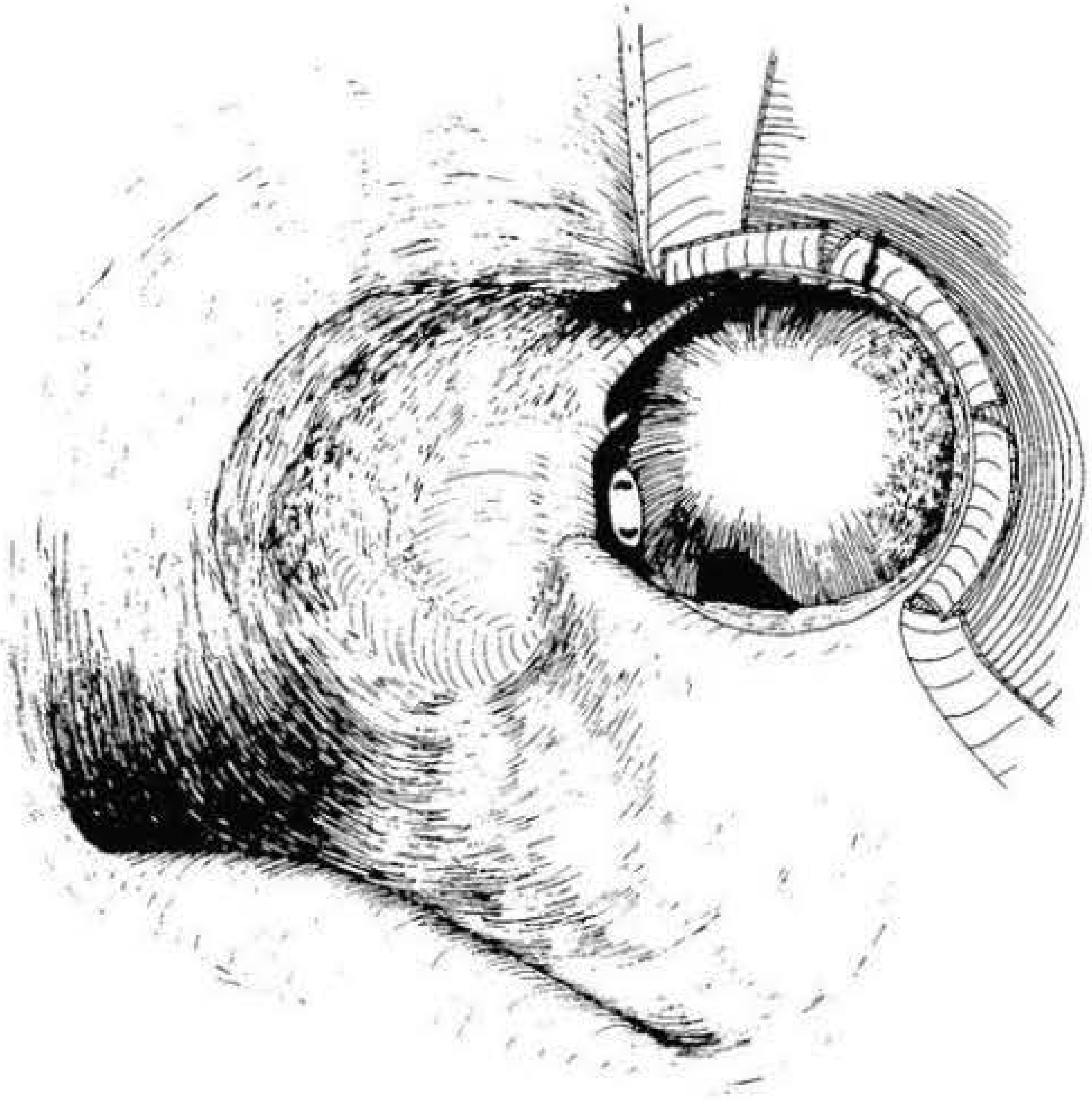


Fig. 23 **The tympanic cavity in the classical radical operation**. The bony annulus of the tympanic ring is drilled away (arrow) in order to expose and enlarge the tympanic cavity. The bony septa in the hypotympanum are lowered. The mucosa of the tympanic cavity is removed. After replacement of the canal skin grafts, the tympanic cavity will epithelialize

In general, the popular terms "radical operation" and "radical cavity" are confusing ones. The present author prefers to use the term "canal wall–down mastoidectomy" (without preservation of the bridge) instead of "conservative" or "modified radical operation." Instead of the term "radical cavity," the term "mastoid cavity," either open (nonobliterated), or partly obliterated will be used here. The term "classical radical cavity" will be used only if no reconstruction of the drum is performed.

Tympanomastoidectomy

Transmastoid tympanoplasty, tympanomastoidectomy, combined-approach tympanoplasty (CAT), or cortical mastoidectomy, are terms denoting an intact canal wall or canal wall–up mastoidectomy with preservation of the bony ear canal wall. The procedure is based on the retroauricular approach.

Several methods of mastoidectomy are used: 1) classic intact canal wall mastoidectomy with posterior atticotympanotomy, by Jansen (1958, 1962) termed posterior tympanotomy. 2) Modifications of intact canal wall techniques. 3) Temporary displacement or removal of the bony ear canal.

Approaches and Routes

The term "approach" means the method of access to the middle ear through the soft tissues; the term "route" means the method of access to the middle ear through the bone. The approaches can be endaural or retroauricular, and superior or anterior. The routes can be transcortical or transmeatal.

The approaches, with their many modifications, have been described in detail in Volume 1. The two most frequently used approaches are the retroauricular (Fig. **24**) and the endaural ones (Fig. **25**). The superior approach has only been used in connection with osteoplastic tympanotomy by S. Wullstein (1974). In the description of the various mastoidectomy techniques, the most commonly used approaches will be briefly described.

Transcortical Route

The transcortical route for drilling starts on the surface of the cortical bone of the mastoid process, behind the bony ear canal, which can remain intact either temporarily or permanently (Fig. **24**). This route is also described as the "outside–in" route, because the initial drilling is always outside. It is necessary to perform the mastoidectomy—at least partly—in order to perform an antrotomy. Atticotomy is also performed through the antrum.

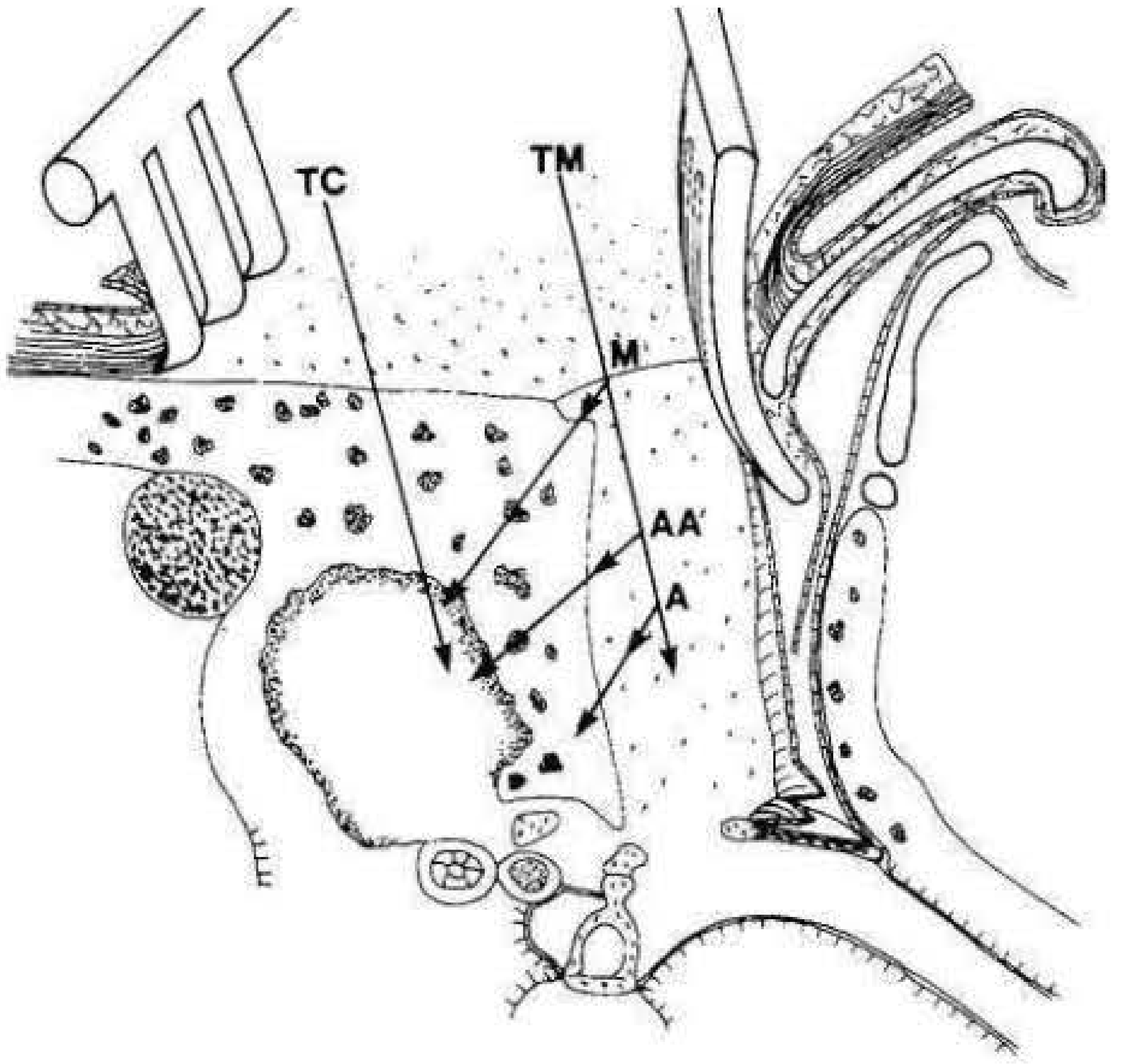


Fig. **24** **The transcortical and transmeatal routes for a mastoidectomy in the retroauricular approach**. The ear canal skin is pushed anteriorly, and its superior part is elevated. The bone work can be performed by a transcortical (outside–in) route or a transmeatal one (inside–out). The transcortical (TC) and transmeatal (TM) routes are indicated, as well as the transmeatal routes for atticotomy (A), atticoantrotomy (AA), and mastoidectomy (M). The dark round dotted area is the sigmoid sinus

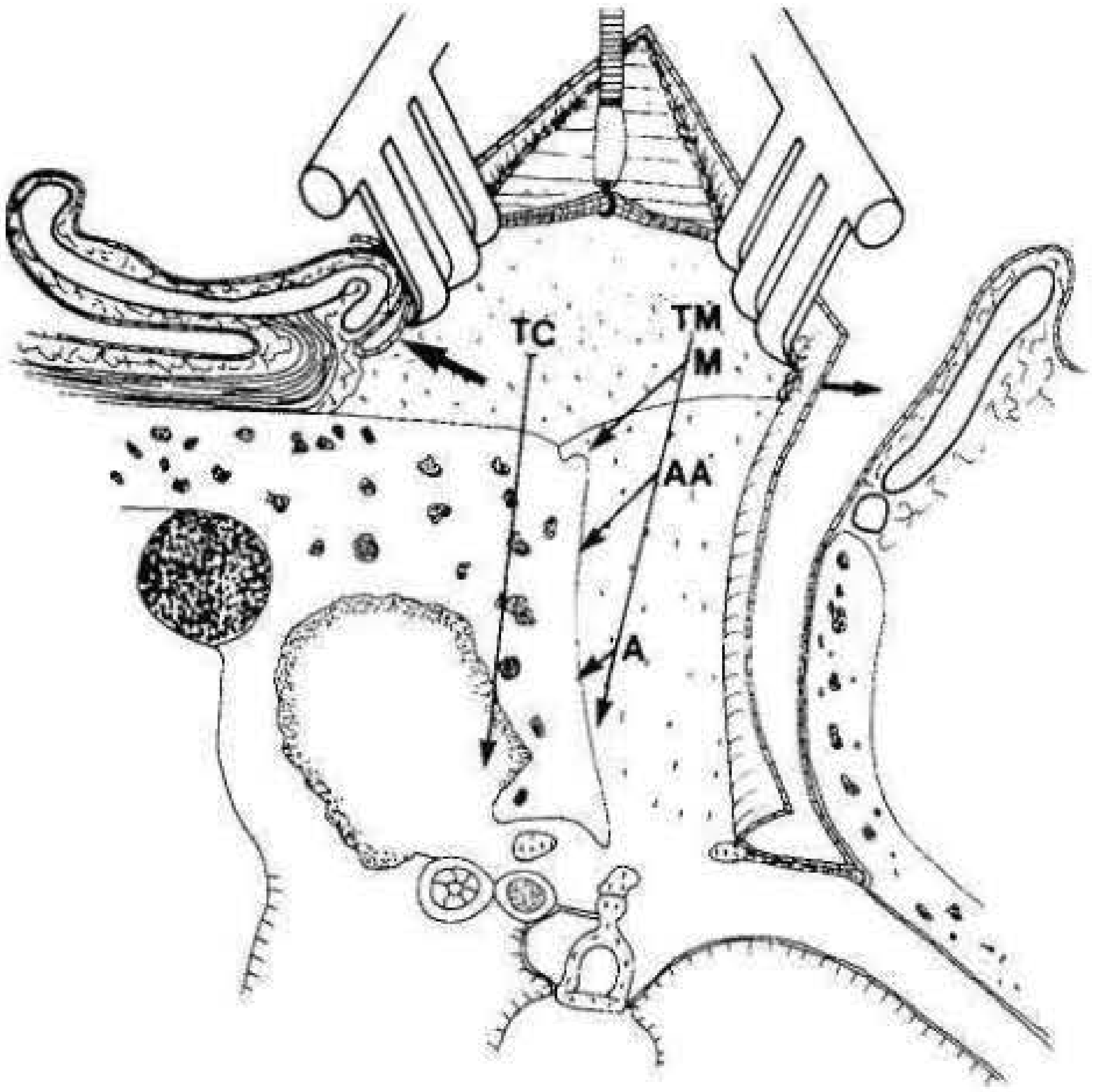


Fig. **25** **The transcortical and transmeatal routes in an endaural approach**. The pinna is retracted posteriorly, and all of the superoposterior meatal bony wall is exposed posteriorly by lateral (large arrow) and anterior (small arrow) displacement of the canal skin. The transcortical route (TC) and transmeatal (TM) routes are indicated, as well as the transmeatal routes for atticotomy (A), atticoantrotomy (AA), and mastoidectomy (M)

Transmeatal Route

The transmeatal (transcanal) route for drilling starts in the bone of the ear canal, either laterally or medially (Fig. **25**). This route is also described as the "inside–out" route, because the initial drilling is from within the ear canal, e. g., with an atticotomy followed by antrotomy and retrograde mastoidectomy (Fig. **26**). Through this endaural route, an atticotomy alone (without mastoidectomy or atticoantrotomy) can be performed. Antrotomy alone (without atticotomy or mastoidectomy) can also be performed. Alternatively, the mastoidectomy can start laterally in the ear canal, as in the transcortical route (Fig. **24**).

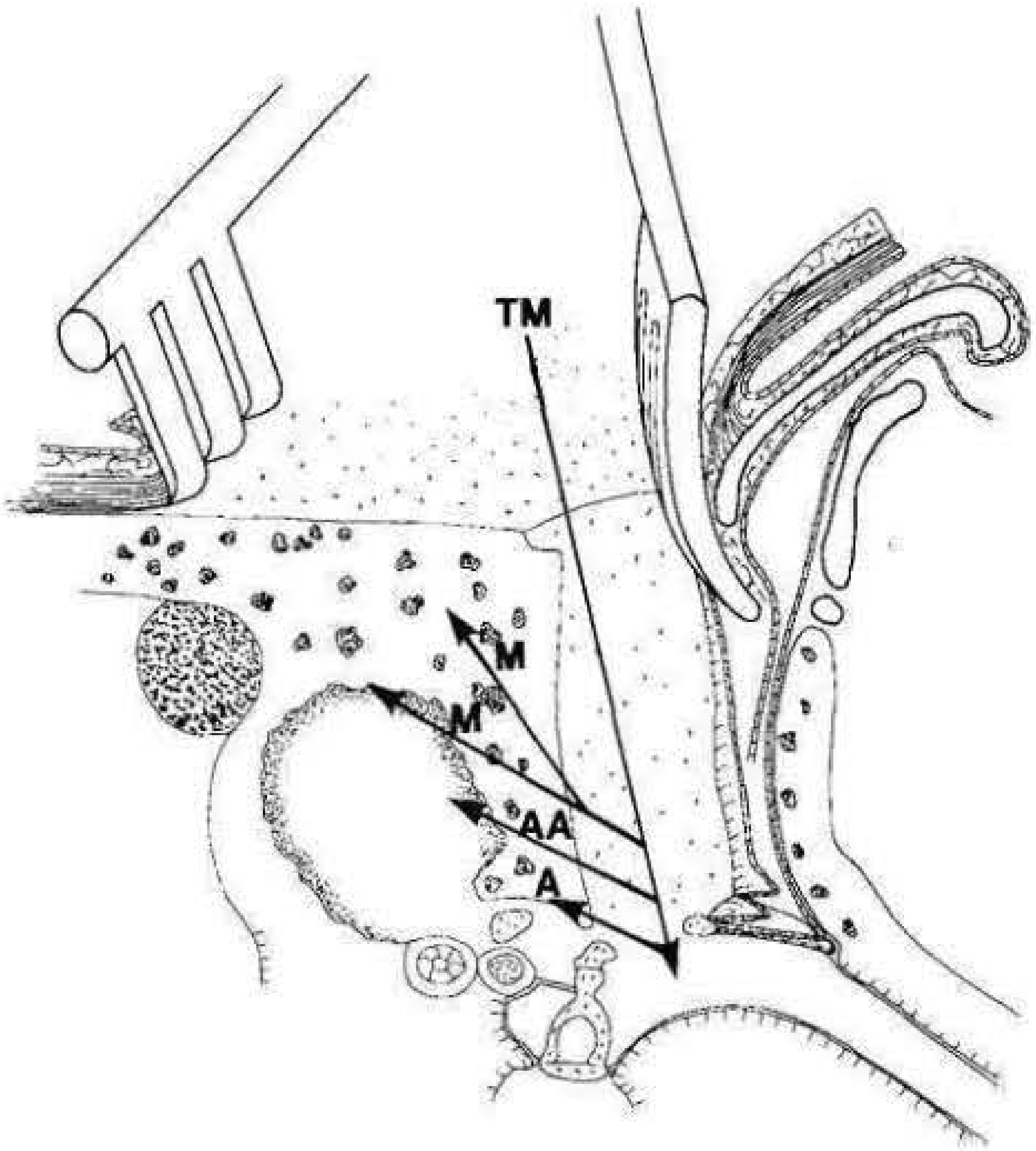


Fig. **26** **The retrograde mastoidectomy in a retroauricular approach and transmeatal (TM) route**. First, an atticotomy (A) is performed and continued posterolaterally, entering the antrum with an atticoantrotomy (AA) and further removal of the mastoid cells laterally and posteriorly, resulting in a retrograde mastoidectomy (M). A typical inside–out mastoidectomy

Approaches and Mastoidectomies

Both the retroauricular approach and the endaural approach, with their many modifications, such as Heermann incisions B and C (Heermann and Heermann 1964), and the Shambaugh (1959), Lempert (1941), Farrior (1968), and Fleury (1974) incisions, are very often used in modern tympanoplasty and mastoidectomy techniques (Volume 1, pp. 15–21). In mastoidectomy, both the endaural and the retroauricular approaches have various advantages and disadvantages:

- The view into the attic in the retroauricular approach is oblique, in the posteroanterior direction. In the endaural approach, the view is direct, lateromedially, and the distance to the attic is shorter than in the retroauricular approach (Figs. **24, 25**).
- The view into the Eustachian tube orifice is good in both approaches, but somewhat better in the retroauricular approach.
- The view into the posterior tympanum and sinus tympani is better in the endaural than in the retroauricular approach.
- Mastoidectomy can easily be extended in the retroauricular approach, but extension is difficult or even impossible in the endaural approach.
- The retroauricular approach is the approach of choice in classic canal wall–up mastoidectomy with posterior atticotympanotomy (Jansen's posterior tympanotomy, 1958, 1962). With the endaural approach, this technique cannot be used.
- Obliteration with muscle flaps, especially using the anteriorly pedicled Palva flap (1962 a, 1962 b, 1963 a, 1963 b) and the inferiorly pedicled Guilford flap (1961), are only possible in the retroauricular approach. In the endaural approach, pedicled muscle flaps are very difficult to use.

The retroauricular approach is increasingly dominating mastoid surgery, partly because of the ease of cavity obliteration and the better access it provides to a large temporal muscle fascia graft, and partly because of the possibility of performing transcortical intact canal wall mastoidectomy with posterior atticotympanotomy. On the other hand, several methods of preserving the intact bony bridge are based exclusively on the endaural approach.

Routes and Approaches

Using the retroauricular approach, both the transcortical and the transmeatal routes to the mastoid for canal wall–up mastoidectomy, atticoantrotomy, and canal wall–down mastoidectomy can be used (Fig. **25**). In fact, the transmeatal route can be employed as easily as the transcortical route (Fig. **25**). With the endaural approach, the transmeatal route is the route of choice. It is the safest, easiest, and fastest route when using this approach (Fig. **25**). An atticotomy usually starts with drilling of the lateral attic wall, and a transmeatal atticoantrotomy follows the atticotomy through further drilling of the ear canal wall. Mastoidectomy or a conservative radical operation can then be performed as a retrograde extension of the atticoantrotomy (Fig. **26**). Transmeatal mastoidectomy can also start laterally at the spine of Henle, with subsequent enlargement of the bony ear canal.

The cavities produced using the retroauricular approach, either by the transcortical or the transmeatal route, are generally larger (Fig. **27**) than the cavities produced using the endaural approach (Fig. **28**). The difference is caused mainly by the less extensive drilling of the cortical bone of the mastoid process required in the endaural approach compared to the retroauricular approach.

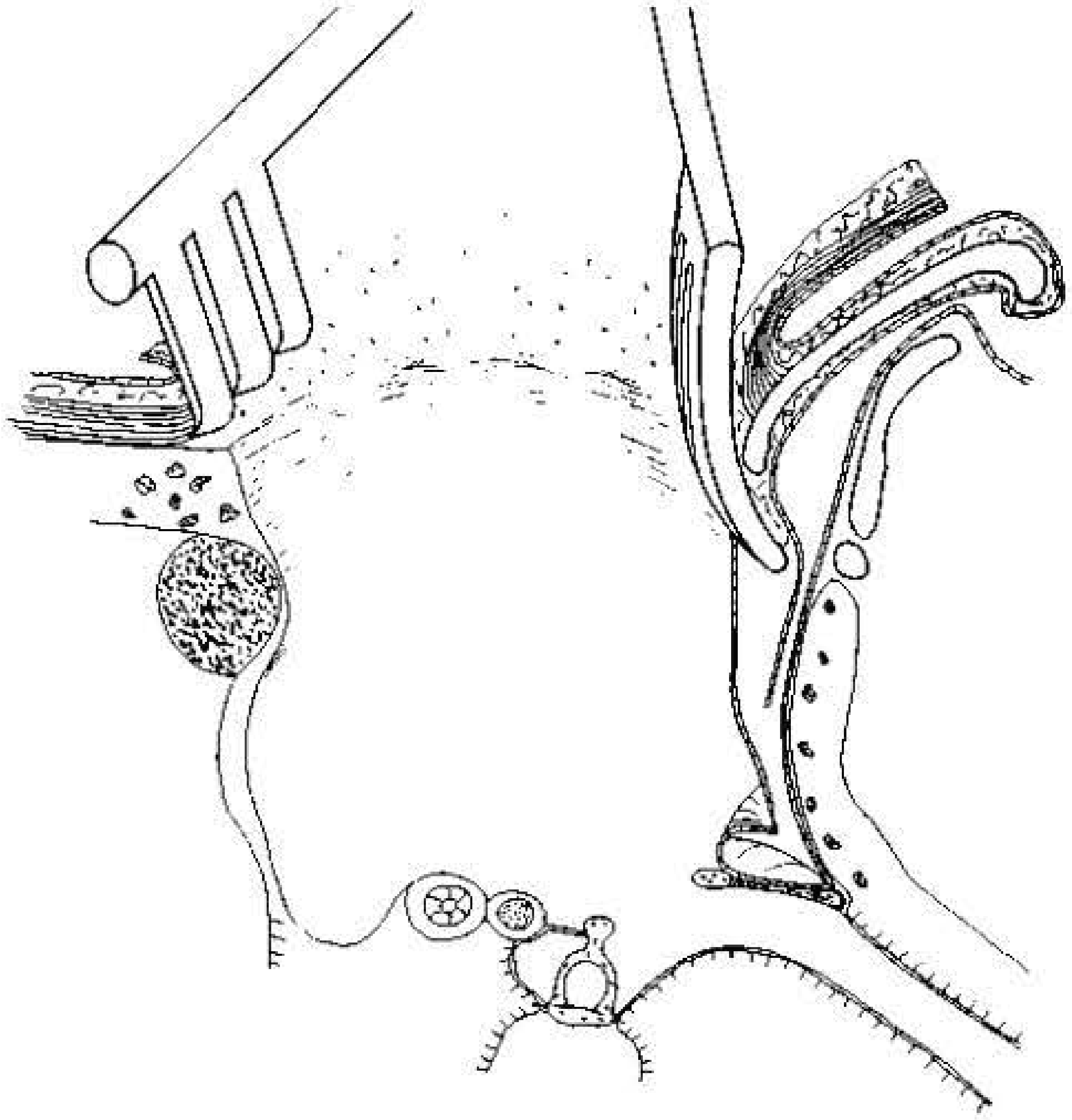


Fig. **27** **Side view of the mastoid cavity obtained in a retroauricular approach** with extensive drilling of the cortical bone at the mastoid plane. Medially, the lateral semicircular canal, facial nerve, stapes, and malleus handle, with the anterior part of the drum, are ilustrated

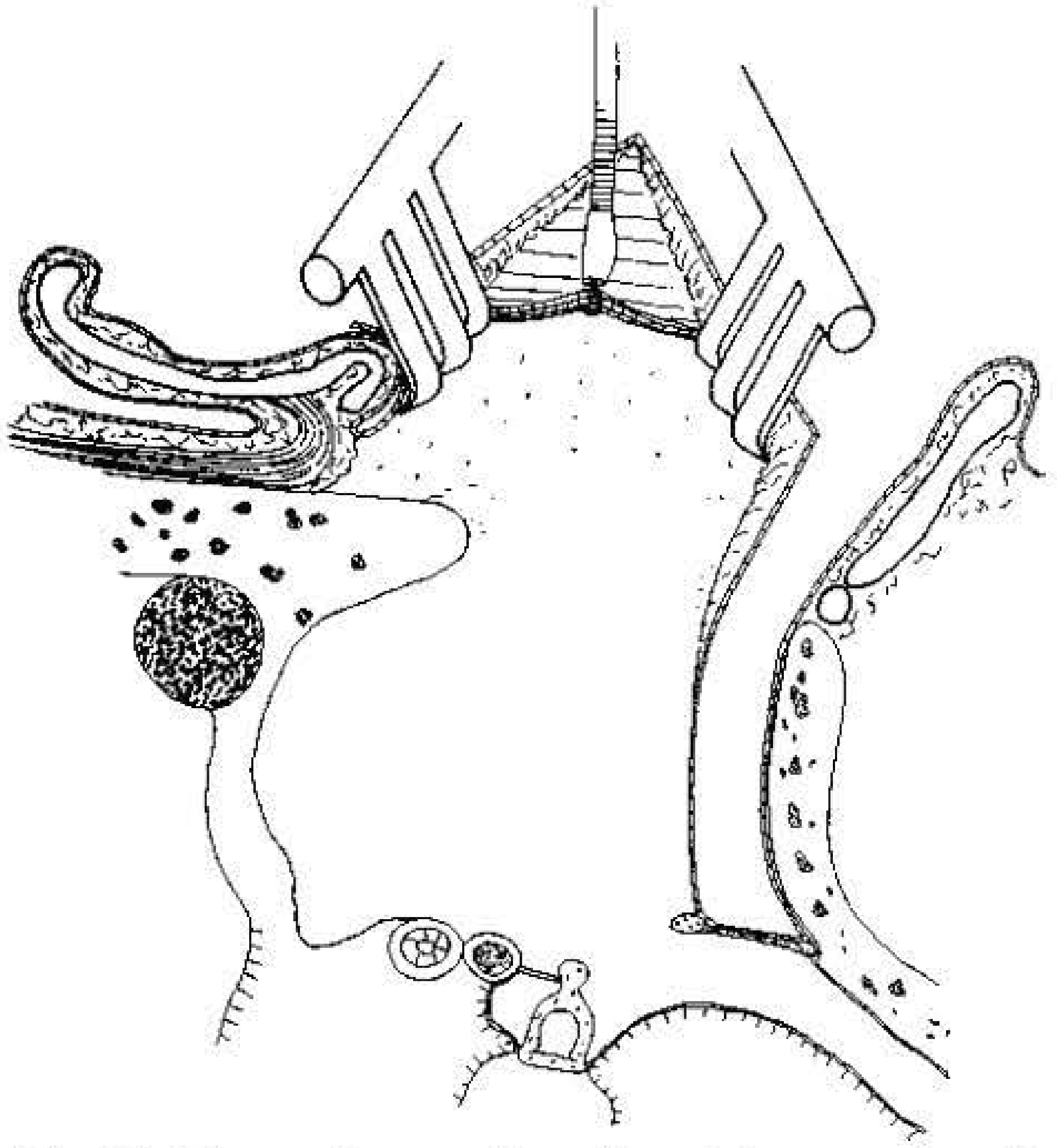


Fig. **28** **The cavity usually achieved in an endaural approach** with less extensive drilling of the cortical bone at the mastoid plane. The dark dotted area is the sigmoid sinus

Canal Wall–Up and Canal Wall–Down Mastoidectomies

The terms "canal wall up" and "canal wall down" have become increasingly popular in modern cholesteatoma surgery. In many schools of thought, mastoidectomies are classified exclusively on the basis of whether the canal wall is removed or remains intact (Table **1**). The fact that the bony ear canal wall sometimes remains only partly intact, e.g., after spontaneous erosion, or is deliberately partly removed, results in several variations or modifications of the canal wall mastoidectomy techniques.

Subclassification of, or synonyms for, canal wall–down mastoidectomy techniques are: atticotomy, Bondy's operation (1910), atticoantrotomy, classical radical operation, retrograde mastoidectomy, and several variations of intact bridge techniques by Paparella and Jung (1983, 1984), Paparella and Shumrik (1988) and Wigand (1967, 1970, 1978). The Paparella method is an open canal wall–down method; the Wigand method, called tympanomeatoplasty with preservation of the bony bridge, is mainly a canal wall–up closed technique, with repneumatization.

The subclassifications of canal wall–up techniques are simple mastoidectomy, cortical mastoidectomy, classic intact canal wall mastoidectomy, combined-approach tympanoplasty, or modifications of these canal wall–up techniques.

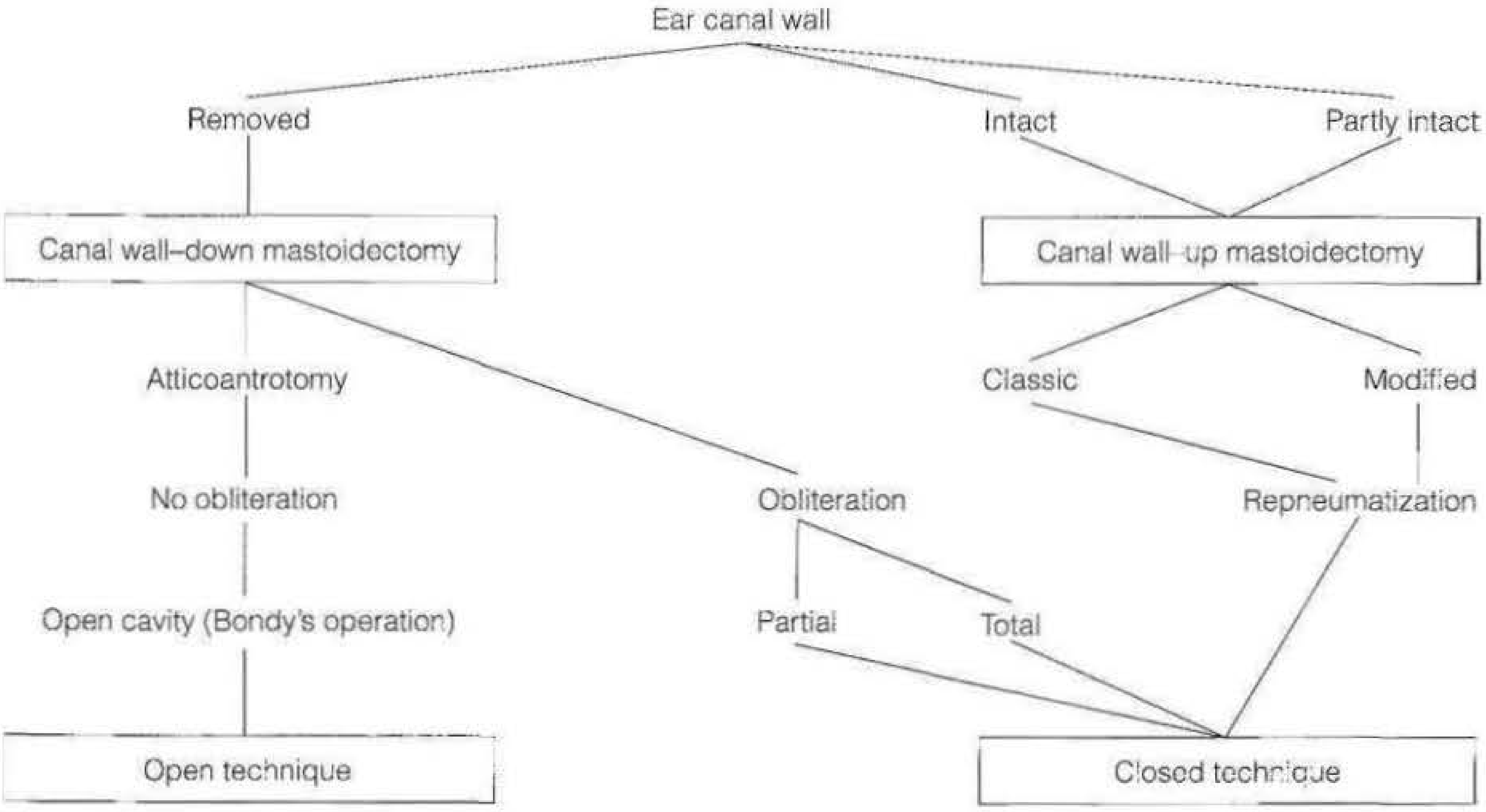
Open and Closed Techniques

The other features of the classification are the obliteration of the cavity or reconstruction of the ear canal, or both.

Open technique. In canal wall–down mastoidectomy, the cavity may remain open, neither obliterated nor with the ear canal reconstructed. The exposed bone is either simply covered with fascia or skin (ear canal skin or split skin grafts), or not covered at all. This type of cavity is lined by granulations and later reepithelialized.

Closed technique. The canal wall–down mastoidectomy cavity can be partly or totally obliterated, and the ear canal partly or totally reconstructed. A totally or partially reconstructed canal wall–down cavity is defined as a closed technique, as is a partially obliterated cavity, for instance when the attic is left open and only the cavity behind it is obliterated. This is defined as a closed technique by most surgeons, but unfortunately there are no clear rules in this respect. A partial obliteration of the mastoid tip alone is defined as an open technique.

Table **1** Classification of mastoidectomies in relation to removal of the bony ear canal wall and obliteration of the cavity



The canal wall–up mastoidectomy cavity can be totally or partially obliterated *behind the intact bony ear canal,* or it can be *repneumatized* in the hope that the cavity will fill with air and remain ventilated. Both principles are closed techniques (Table **1**).

Classic Canal Wall–Up Mastoidectomy

Canal wall–up mastoidectomy, also described as the classic intact canal wall mastoidectomy or combined-approach tympanoplasty (Jansen 1958, 1962) is defined as a mastoidectomy with an entirely preserved, but thinned, bony ear canal wall (Figs. **29**, **30**). The disease from the attic is removed through careful drilling of all the bone between the ear canal and the tegmen tympani and hence enlarging access to the attic. Access to the tympanic cavity is achieved by a so-called posterior tympanotomy (Jansen 1958, 1962), which the present author prefers to call posterior atticotympanotomy (Fig. **31**). The goal of intact canal wall mastoidectomy is to repneumatize the mastoid cavity.

Several modifications of intact canal wall mastoidectomy have been described and used, but in several so-called intact canal wall methods, the bony ear canal is not intact at all, partly because of the extensive drilling of the medial ear canal wall, and partly because of the spontaneous resorption of the lateral attic wall.

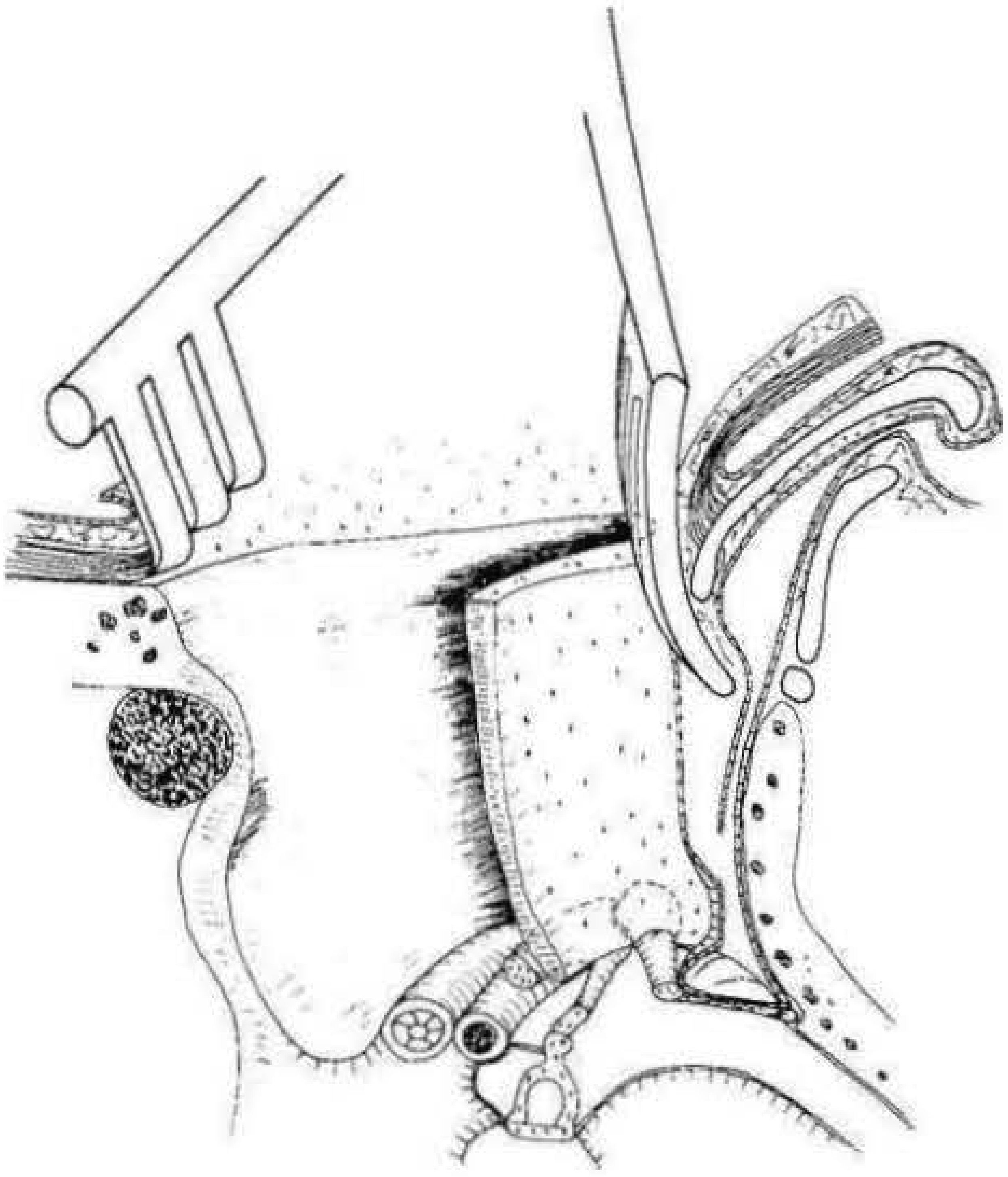


Fig. **30** **Perspecitve side view of the intact canal wall mastoidectomy in a retroauricular approach** on the superior half of the cavity. The ear canal, lateral semicircular canal, facial nerve, and intact ossicles are intended to illustrate the ear canal changes in this and the following figures, which will therefore be termed perspecitve side views

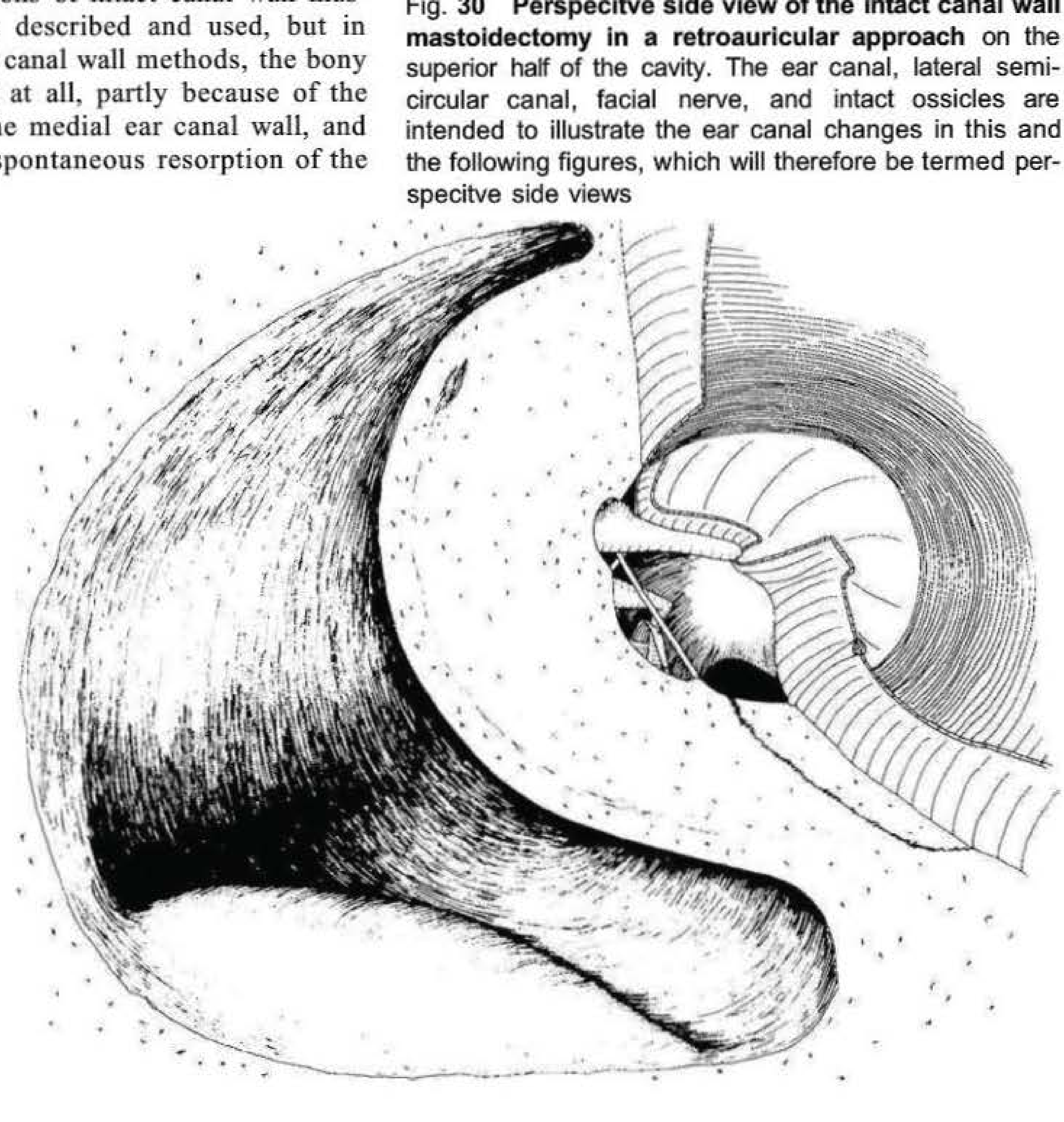


Fig. **29** **The classic intact canal wall mastoidectomy** with an entirely intact, but thinned, bony ear canal wall

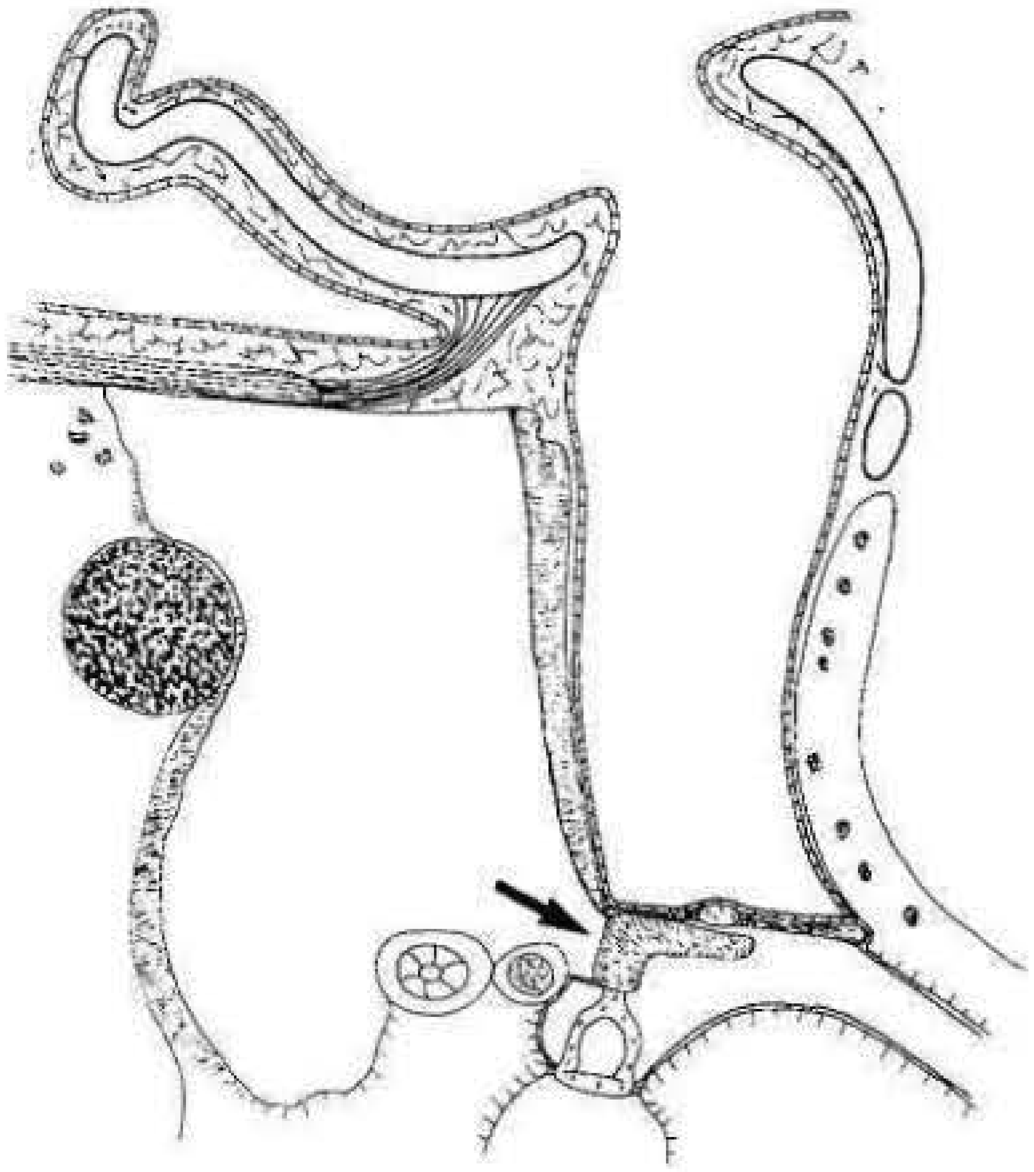


Fig. 31 **Side view of a classic intact canal wall mastoidectomy.** The posterior canal wall is thin, and there is a broad communication between the attic and the tympanic cavity achieved with posterior atticotympanotomy (arrow). An incus interposition is performed. The cavity behind the intact canal wall will be repneumatized

Modifications of Intact Canal Wall Mastoidectomy

Modifications of intact canal wall mastoidectomy are:

- Atticotomy with preservation of the intact bony bridge.
- Atticotomy with preservation of a partly resorbed bony bridge.
- Atticotomy with removal of the bridge.
- Widening of the ear canal.

Atticotomy openings of various sizes with preservation of the intact nonresorbed bony bridge (Fig. **32**). The present author introduced this method, and has used it since 1971 and reported on 2–5 year follow-up results for 159 ears with cholesteatoma (Tos 1978 a). The goal of the atticotomy is to obtain a good view into the anterior attic (Fig. **33**). The bridge remains in its normal position.

Atticotomy openings of various sizes with preservation of a partly resorbed bony bridge (Fig. **34**) (Tos 1978 a, Tos 1982 a). In cases in which there is spontaneous resorption of the lateral attic wall due to attic cholesteatoma, an atticotomy has to be performed superiorly to the resorbed bridge, resulting in displacement of the new bridge superiorly and laterally (Figs. **35, 36**). Sometimes, resorption of the lateral wall of the attic can be more extensive, so that the atticotomy has to be performed further laterally, and the bony bridge in such cases is displaced further superolaterally (Figs. **37, 38**).

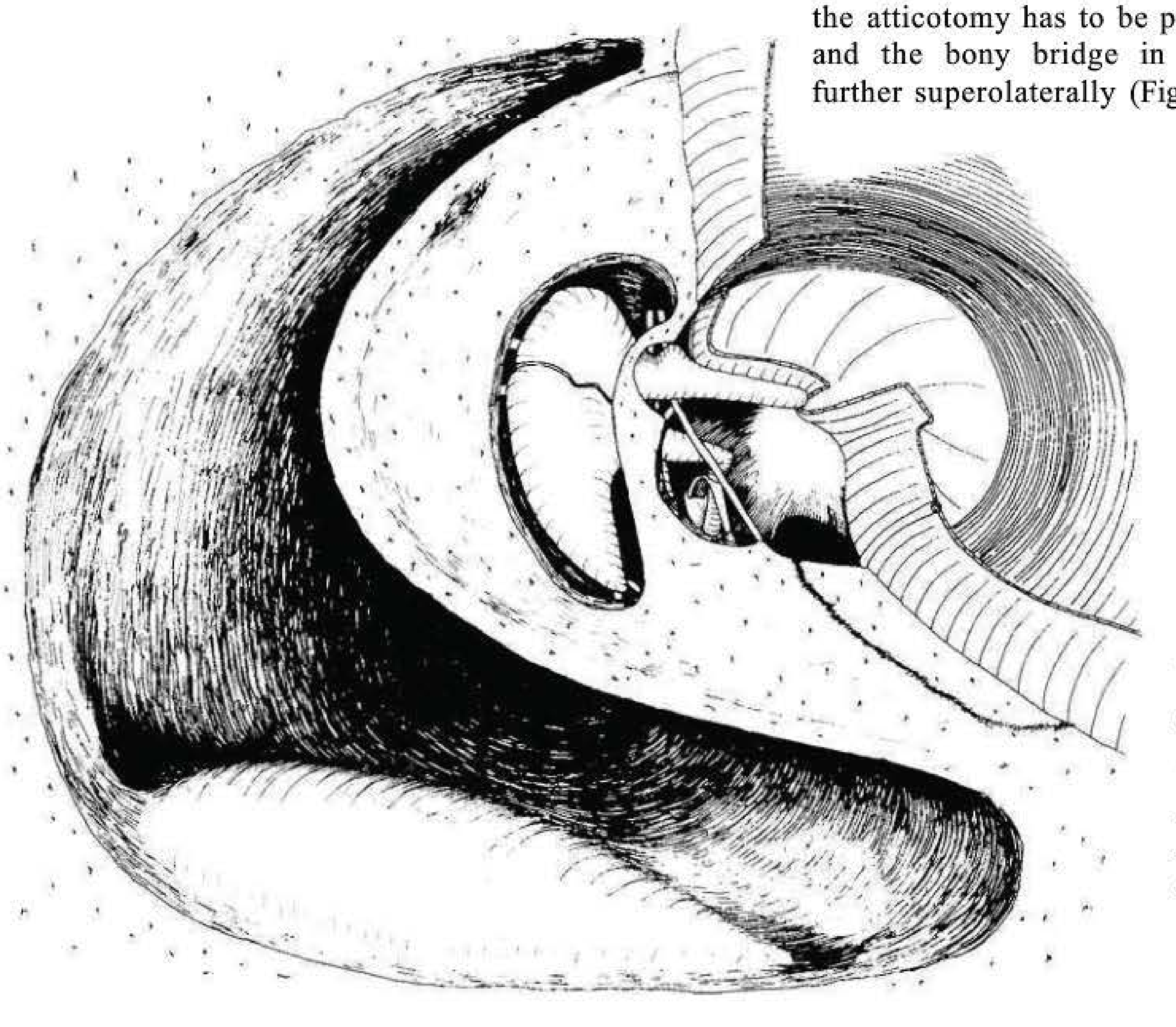


Fig. **32** **The present author's modification of an intact canal wall mastoidectomy with an atticotomy** (also called modified combined approach tympanoplasty), preserving the bridge to achieve a better view into the attic. The bony bridge is in its normal position (Tos 1978 a)

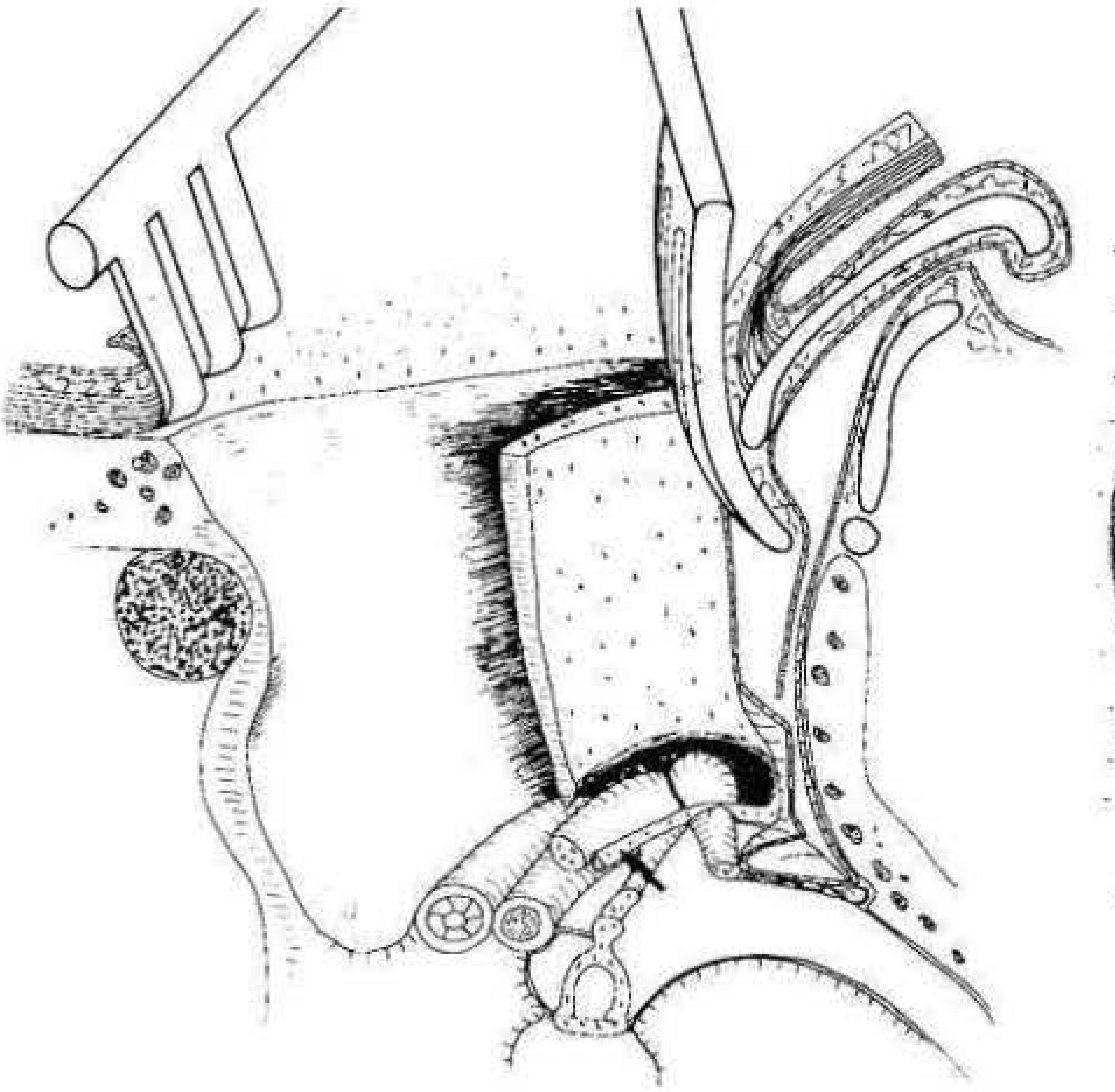


Fig. **33** **Perspective side view** of the present author's modification of intact canal wail mastoidectomy with atticotomy and preservation of a thin bony bridge (arrow), which is in its normal position

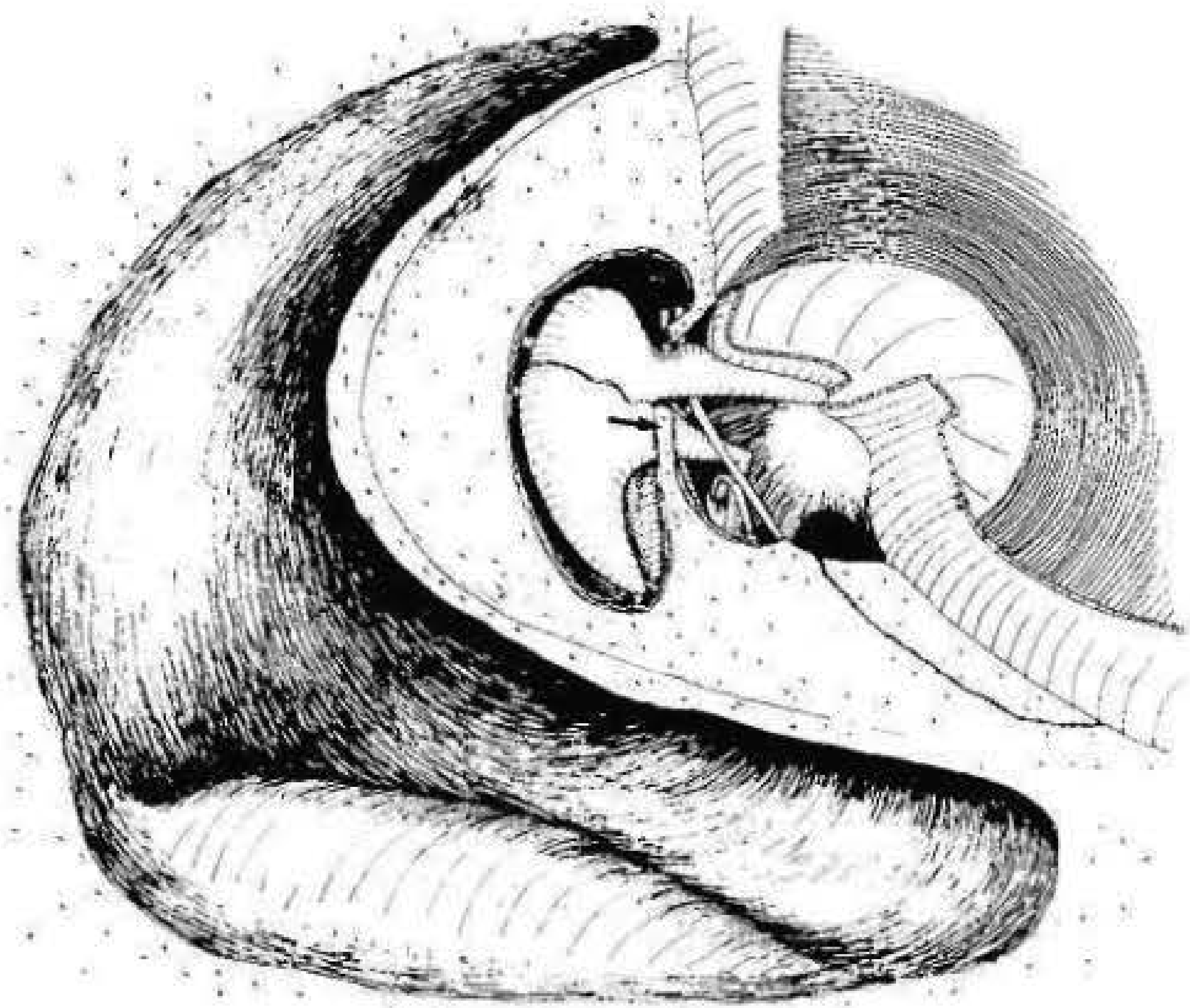


Fig. **34** **Modification of intact canal wall mastoidectomy with an atticotomy** in a case with resorption of the bridge, which is only partly preserved (arrow)

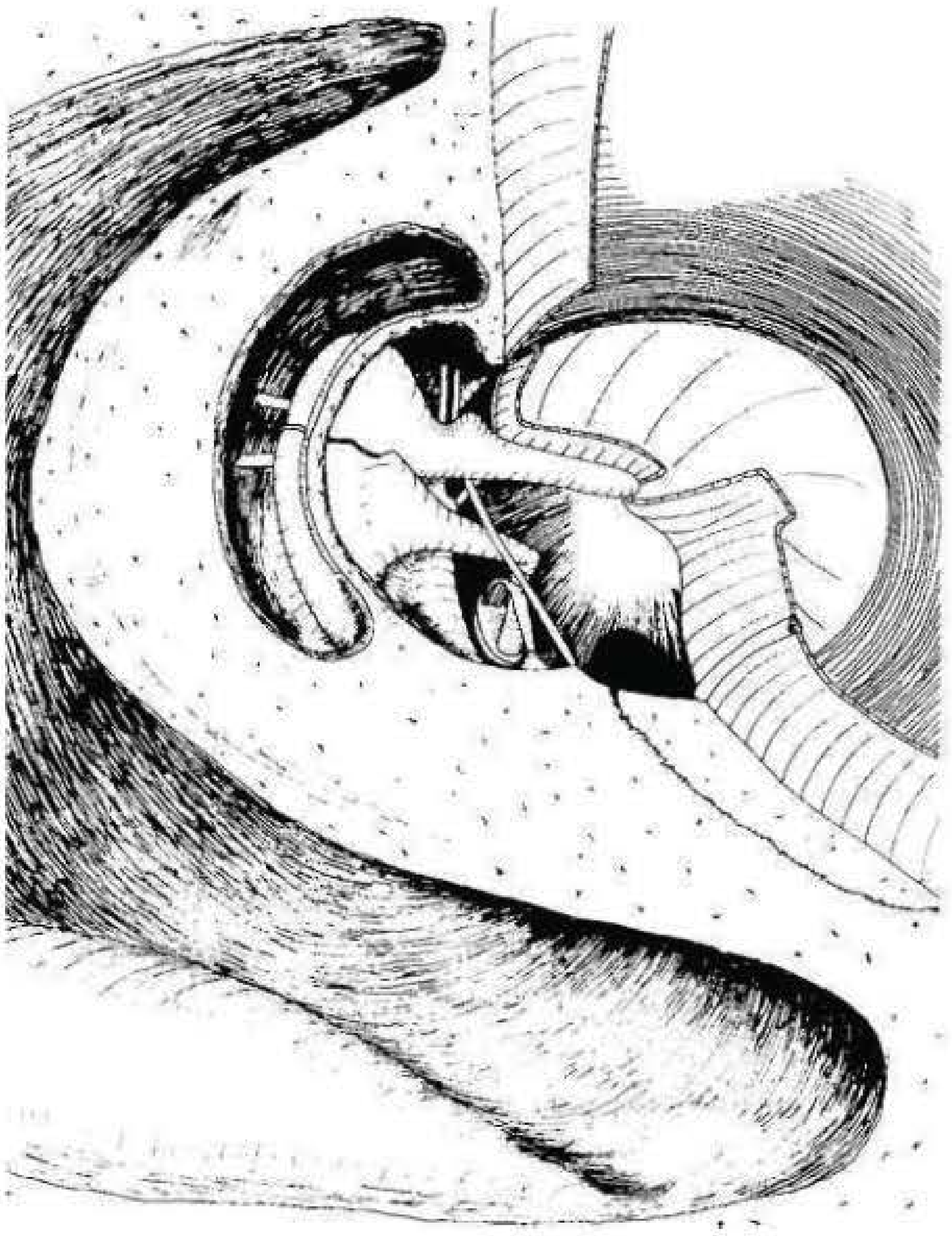


Fig. **35** **The present author's modification of intact canal wall mastoidectomy** in a case of attic cholesteatoma with some spontaneous erosion of the lateral attic wall. An atticotomy is performed superiorly to the bridge, which is therefore displaced superolaterall

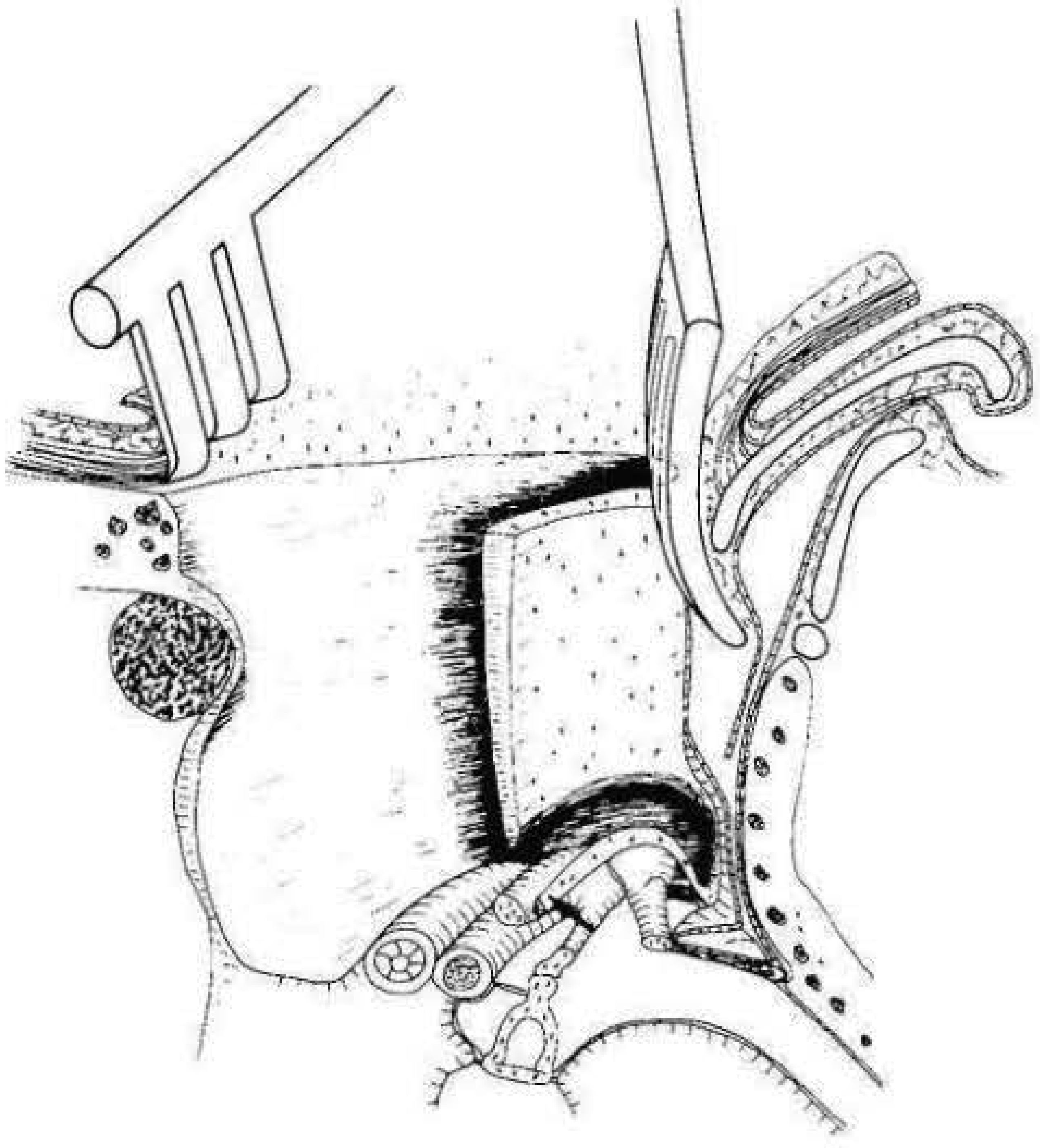


Fig. **36** **Perspective side view of an atticotomy** in a case with spontaneous resorption of the scutum. The bridge is displaced superolaterally (arrow)

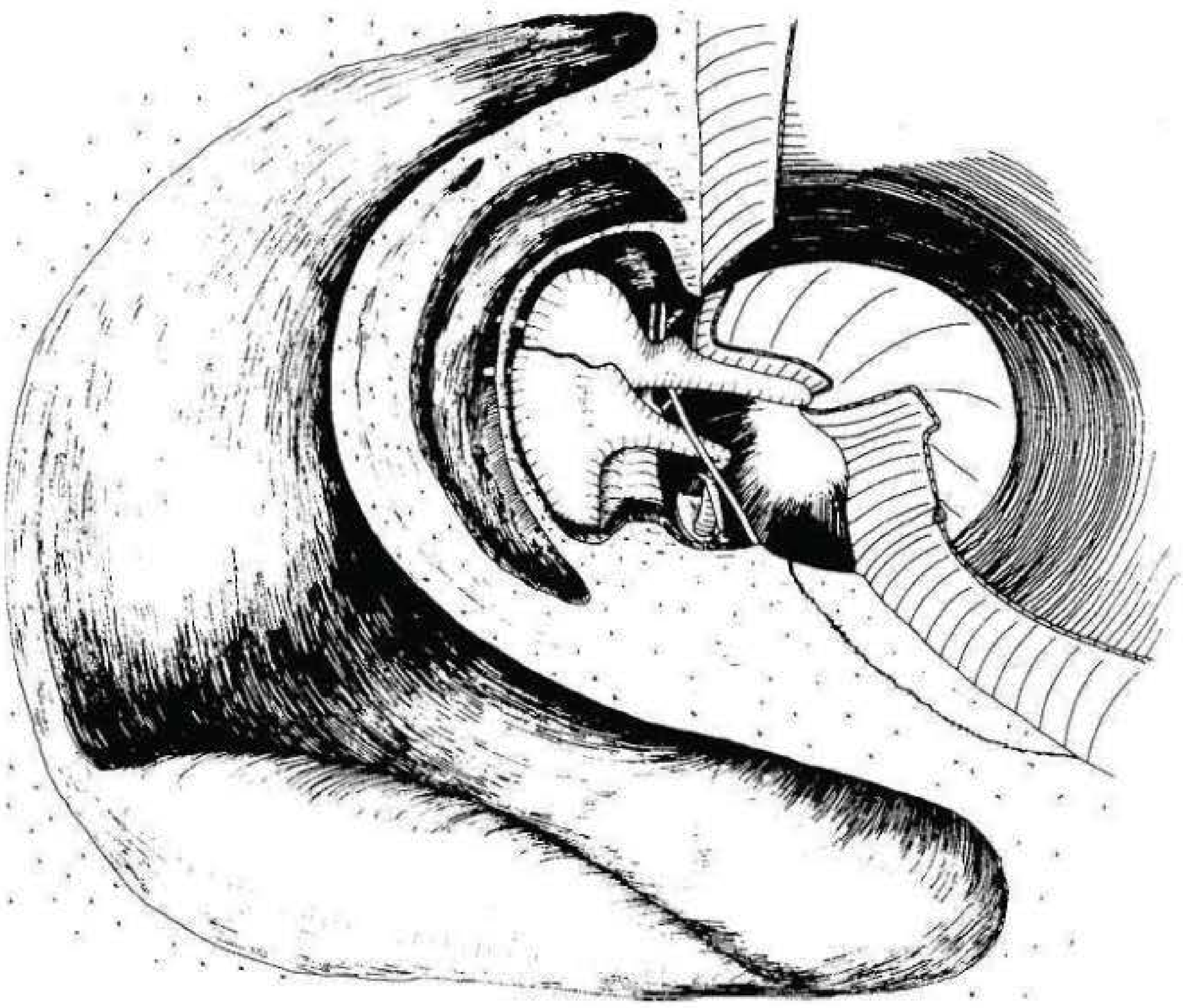


Fig. **37** **A high atticotomy** in a case with extensive spontaneous resorption of the lateral attic wall. The atticotomy is extended posteriorly towards the antrum. The bridge is displaced superolaterally

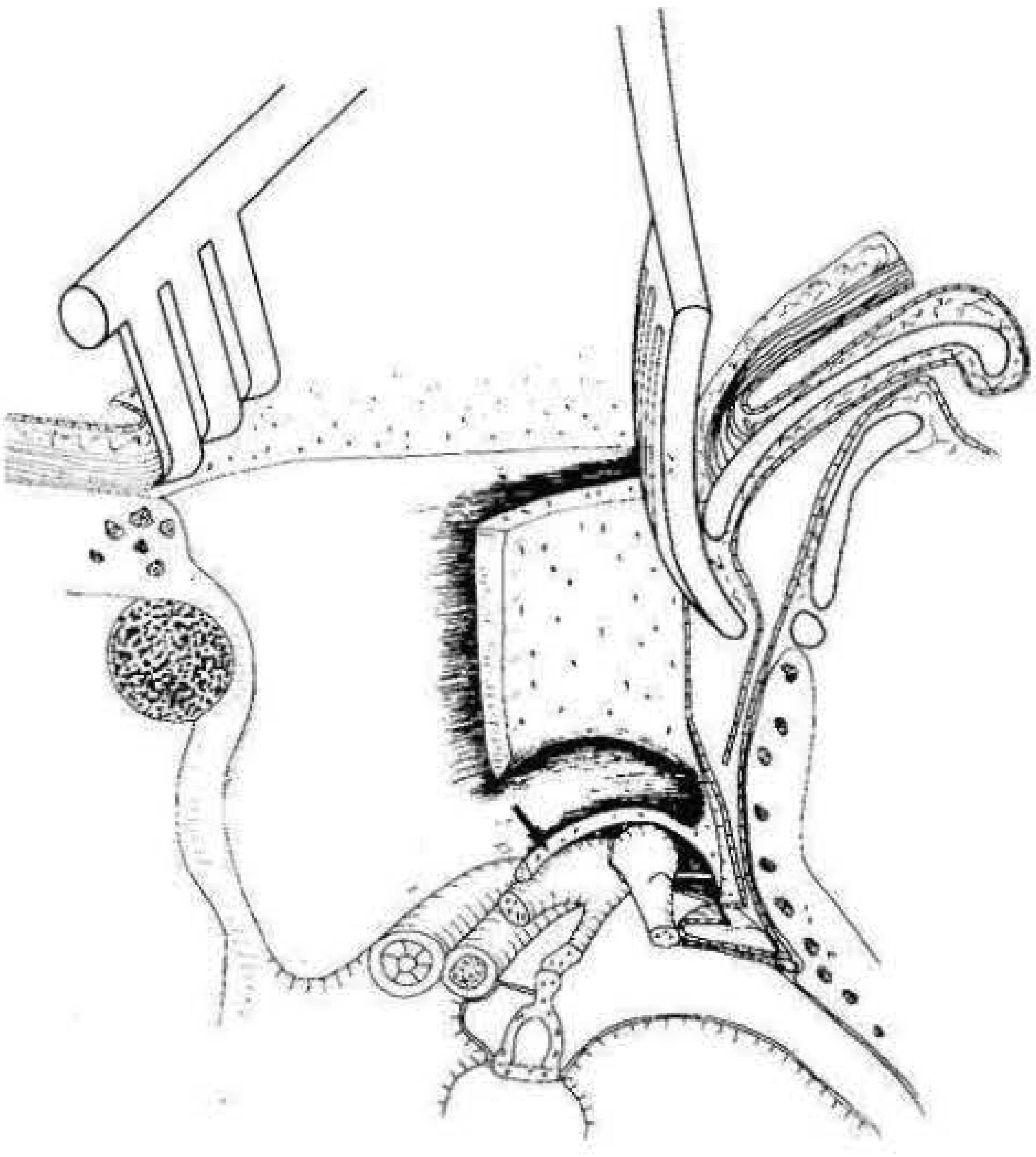


Fig. **38** **Perspective side view in a high atticotomy** in a case of extensive resorption of the lateral attic wall. The atticotomy is placed rather laterally and the preserved bridge (arrow) is therefore displaced superiorly, laterally and posteriorly in relation to the normal position of the bridge and in relation to the incus and malleus

Atticotomy openings of various sizes with removal of the bony bridge (Fig. **39**). Removal of the lateral attic wall is used by Morimitsu (1991) in his modification of intact canal wall mastoidectomy. Morimitsu called this procedure anterior tympanotomy (Fig. **40**). In cases with resorption of the lateral attic wall, only limited removal of the bridge is necessary. A larger atticotomy, with removal of the bridge and total exposure of the attic, is used to obtain better exposure of the anterior attic (Rosborg 1993) (Figs. **41**, **42**). After extensive removal of the lateral attic wall and a large atticotomy, only the lateral half of the ear canal wall is intact (Figs. **43, 44**).

Widening of the ear canal. By drilling the lateral part of the ear canal, better access to the tympanic cavity can be achieved. The superior wall of the ear canal can be drilled away, exposing the lateral attic (Fig. **45**), the tegmen antri, and the tegmen tympani. With continued drilling of the ear canal, an atticoantrotomy can be performed, but if a mastoidectomy is performed, a special modification of the canal wall up mastoidectomy results in the entire ear canal being displaced posteriorly in relation to its normal position, with the attic being exposed.

The bridge can be preserved (Fig. **45**) or removed (Fig. **46**). Usually, the ossicular chain is not intact (Fig. **47**).

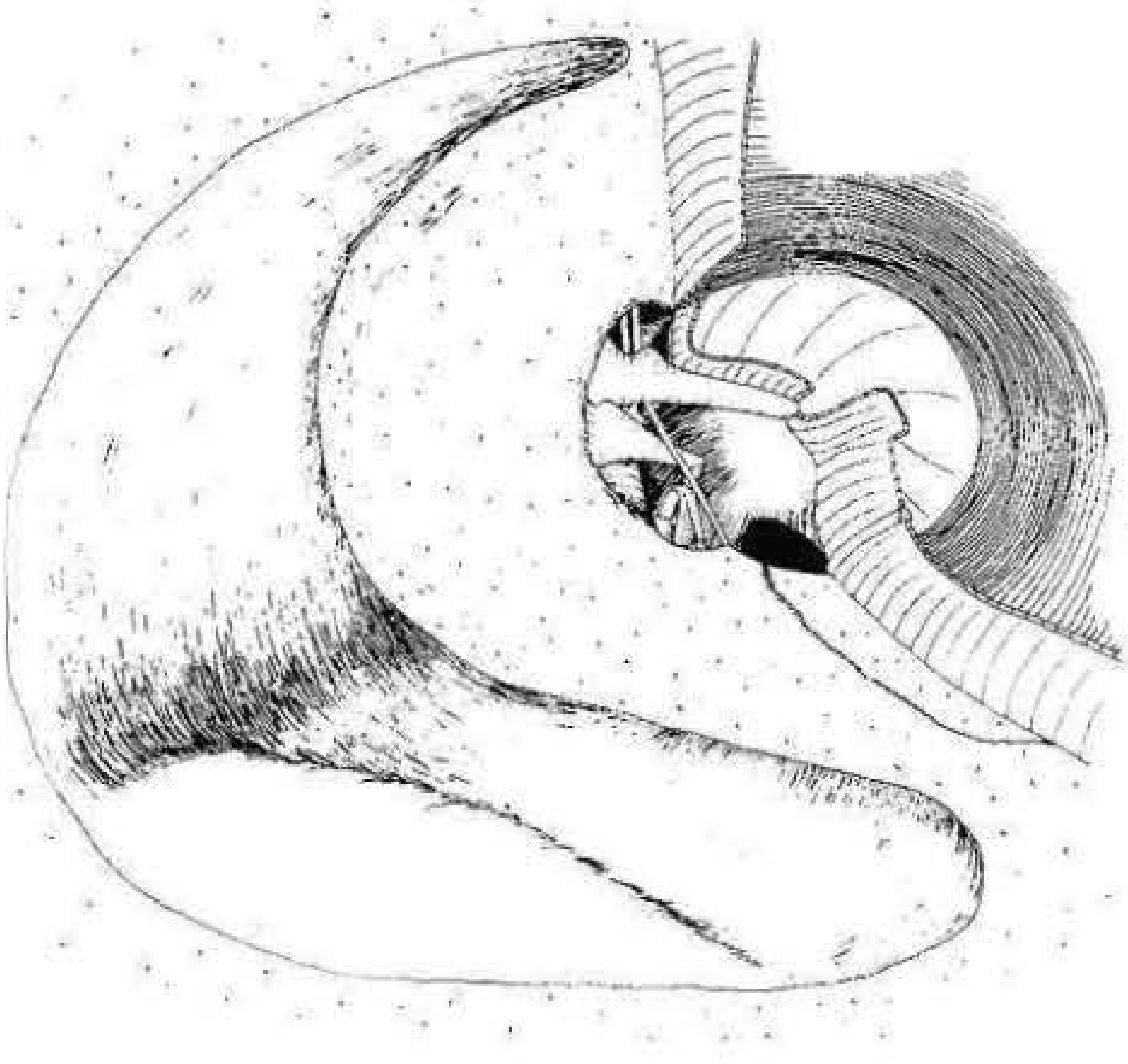


Fig. 39 **Classic intact canal wall mastoidectomy** with some drilling of the lateral attic wall exposing a part of the lateral attic, especially anteriorly

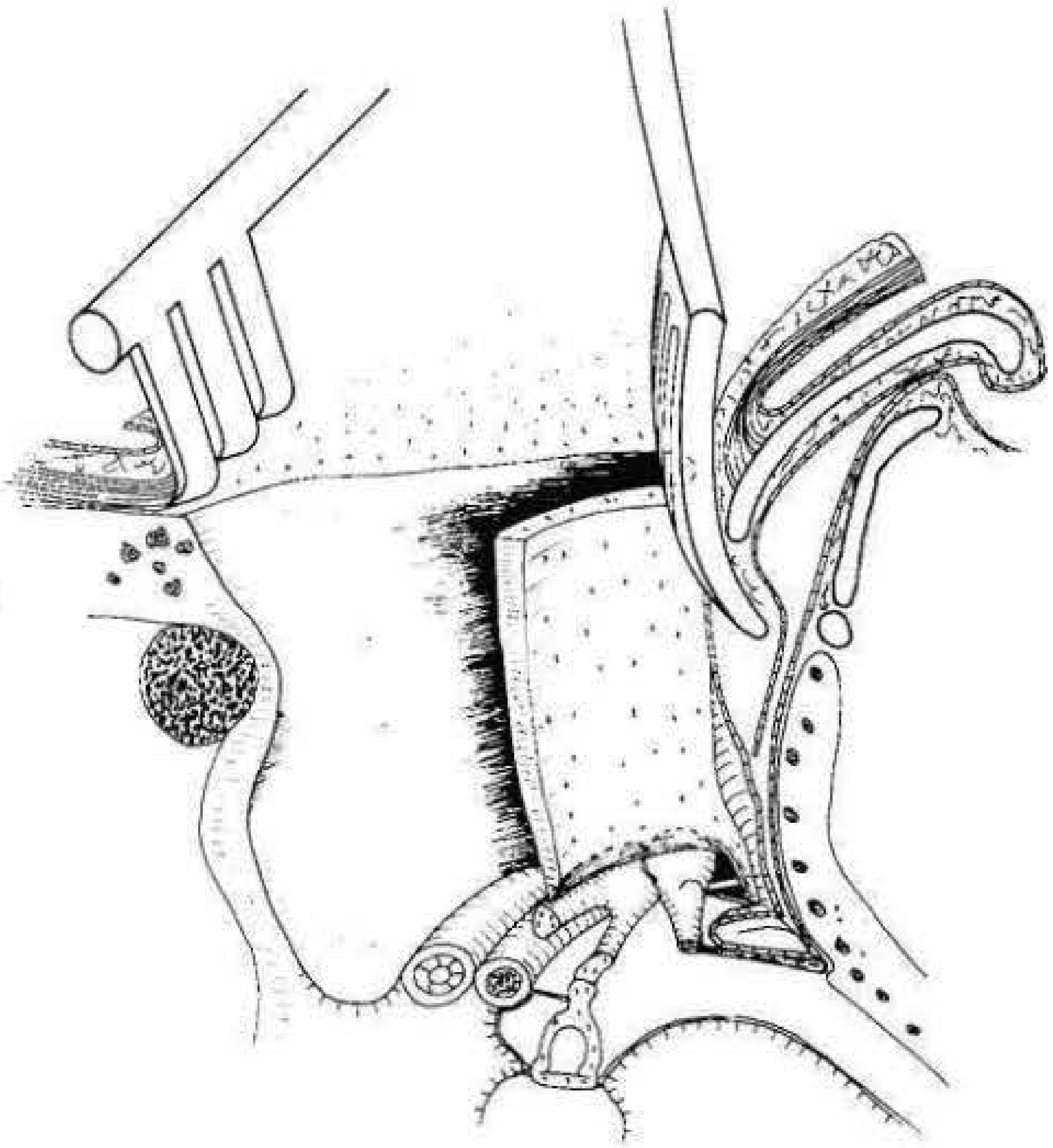


Fig. 40 **Perspective side view of the classic intact canal wall mastoidectomy** with the medial part of the ear canal drilled off, exposing a part of the attic. In fact, in this case a small atticotomy was performed

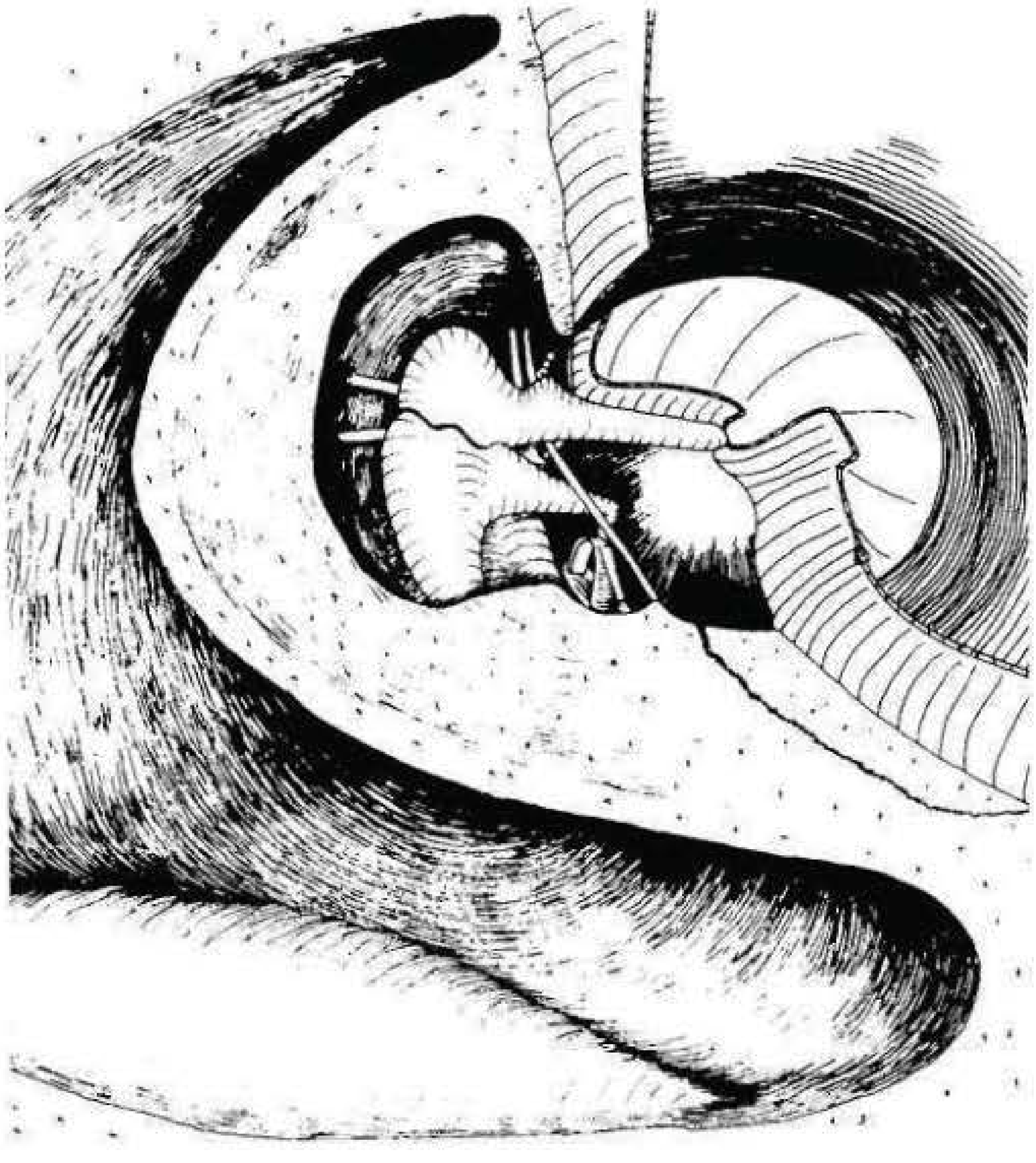


Fig. 41 **Canal wall–up mastoidectomy with a large atticotomy** and removal of the bony bridge

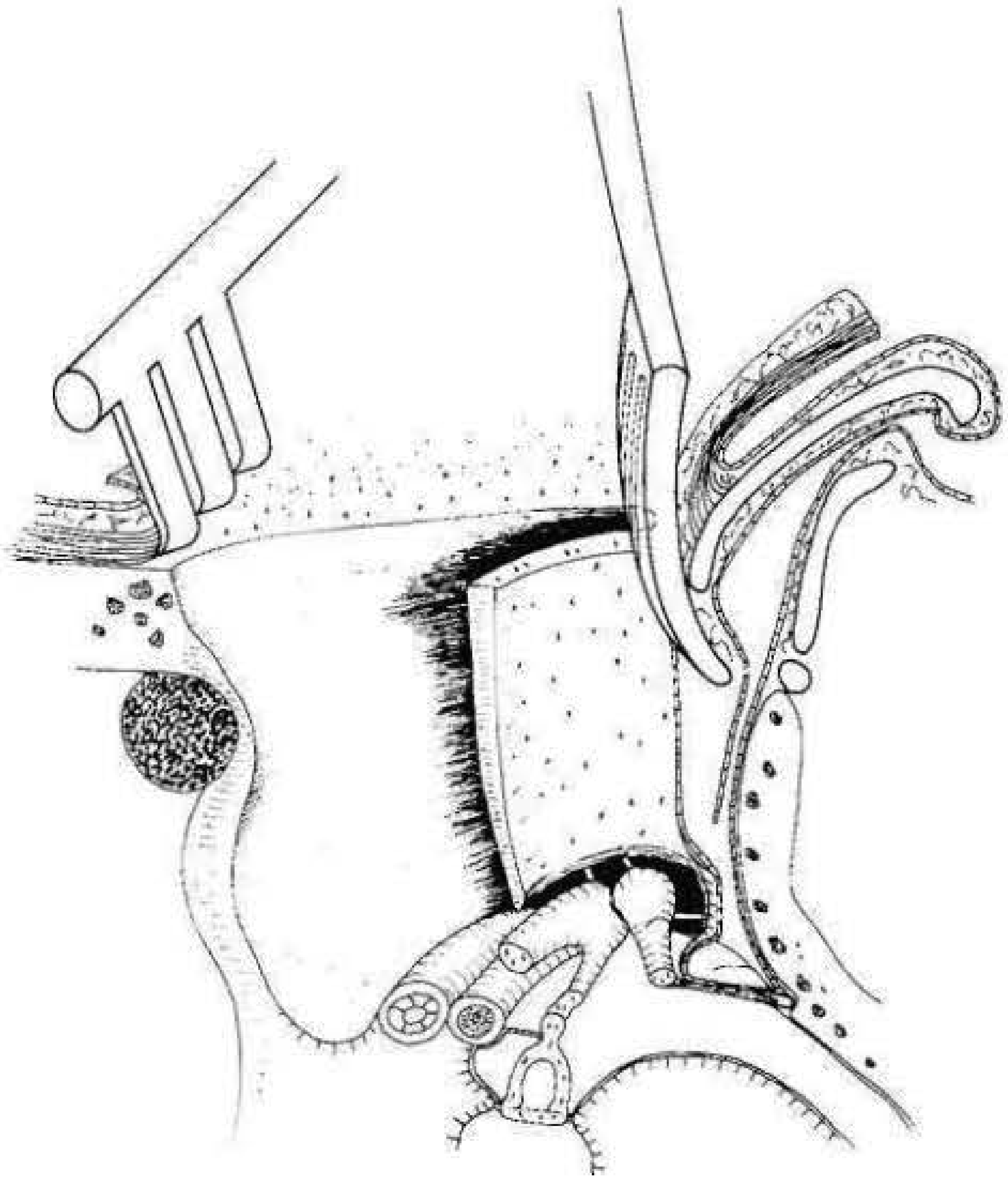


Fig. 42 **Perspective side view of a large atticotomy,** exposing the incus and the malleus

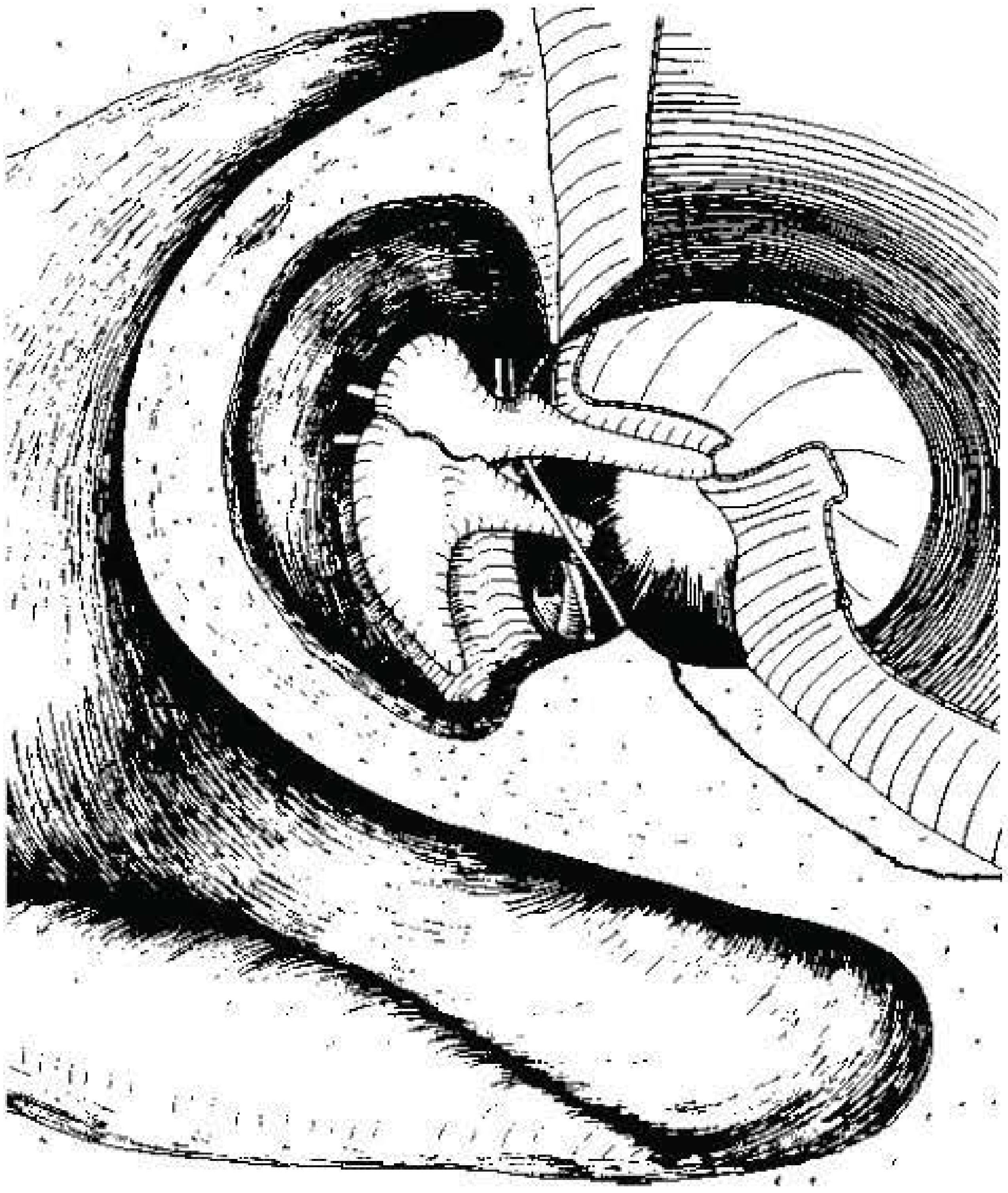


Fig. **43** **Canal wall–up mastoidectomy with a large atticotomy** posteriorly involving the antrum as well

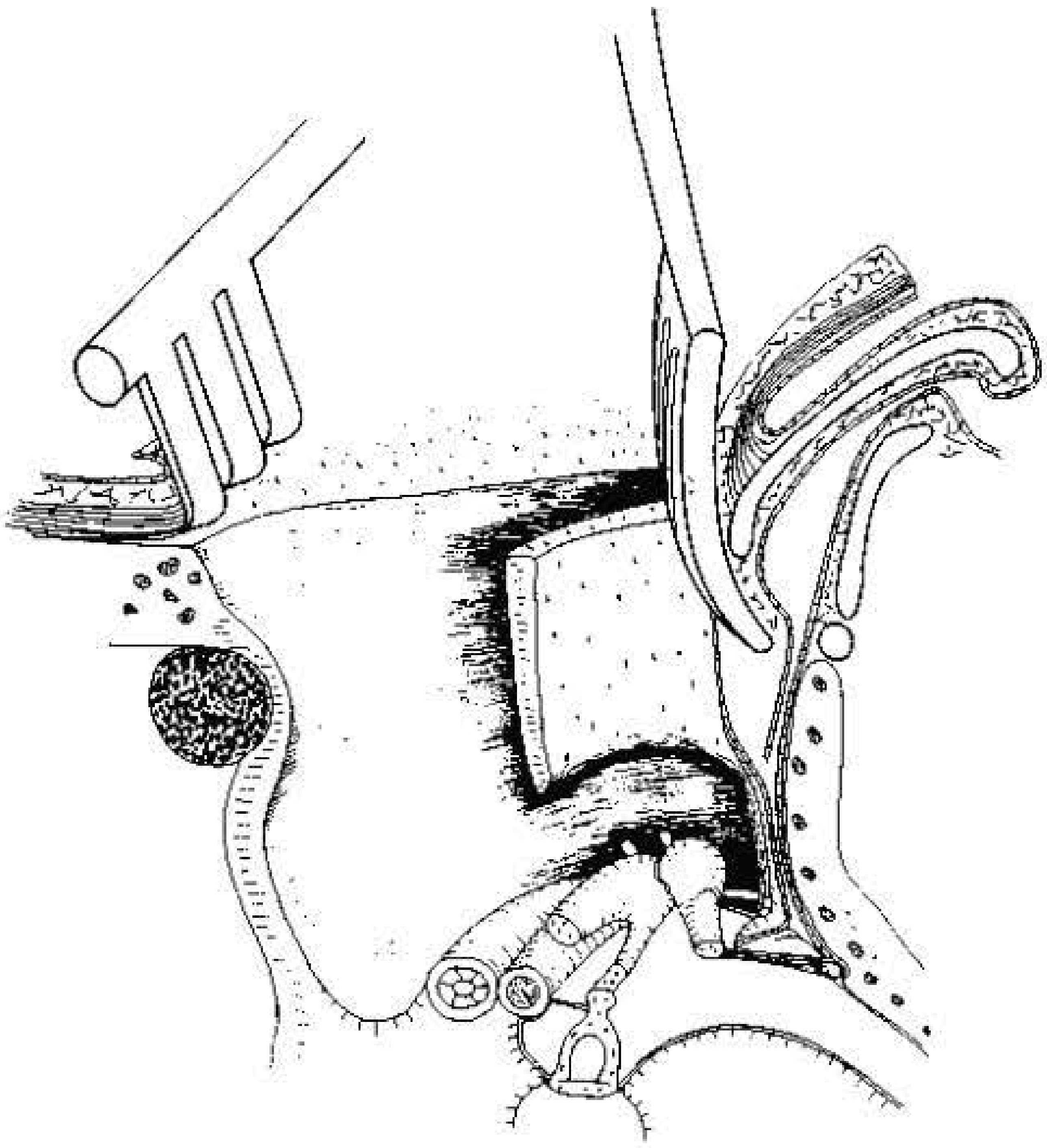


Fig. **44** **Perspective side view of an intact canal wall mastoidectomy with a large atticotomy** and removal of the medial half of the bony ear canal wall. Only the lateral half is intact and preserved

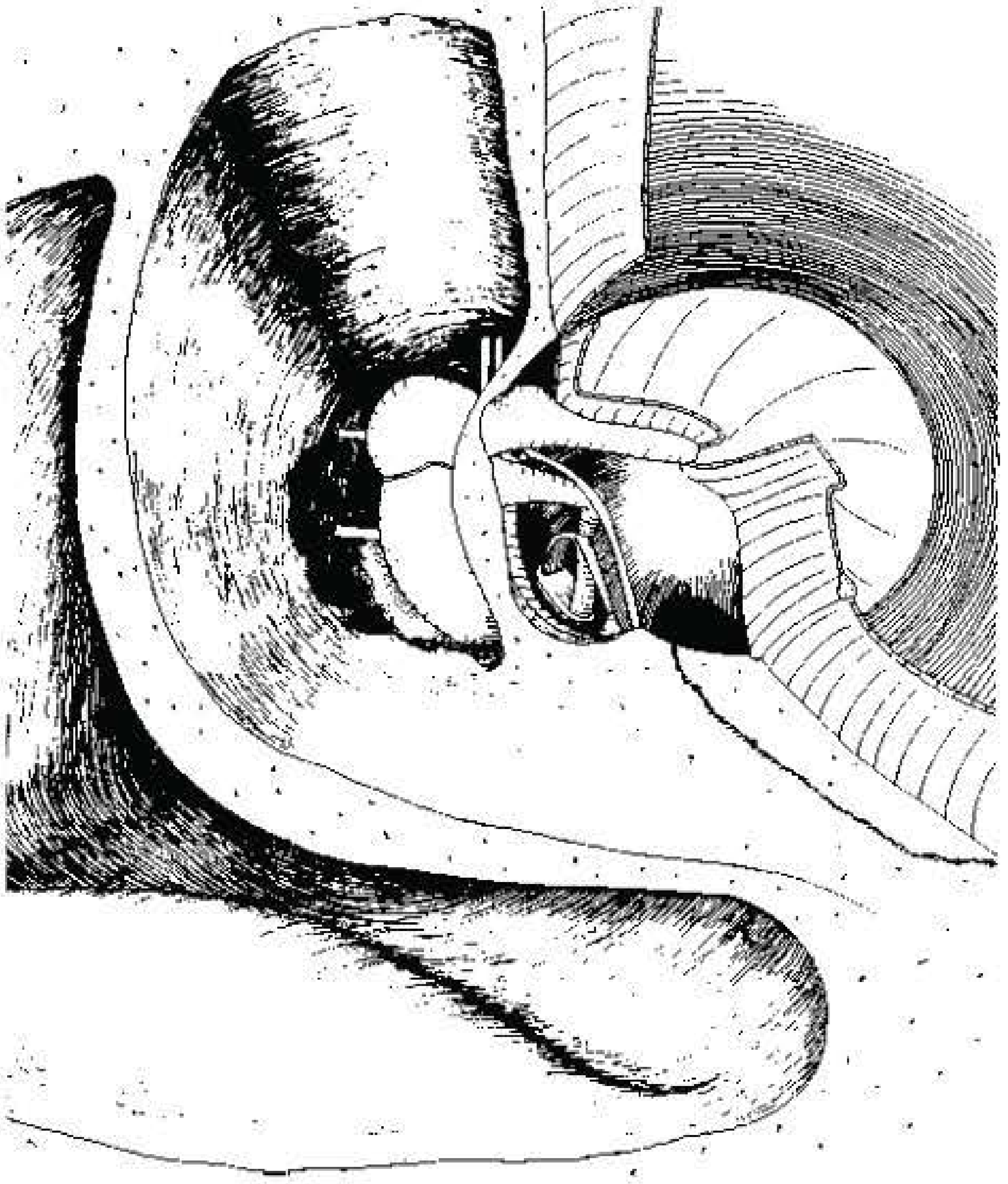


Fig. **45** **Widening of the lateral part of the ear canal combined with an atticotomy with preservation of the bridge.** The entire ear canal is displaced superoposteriorly, and behind it a mastoidectomy is performed

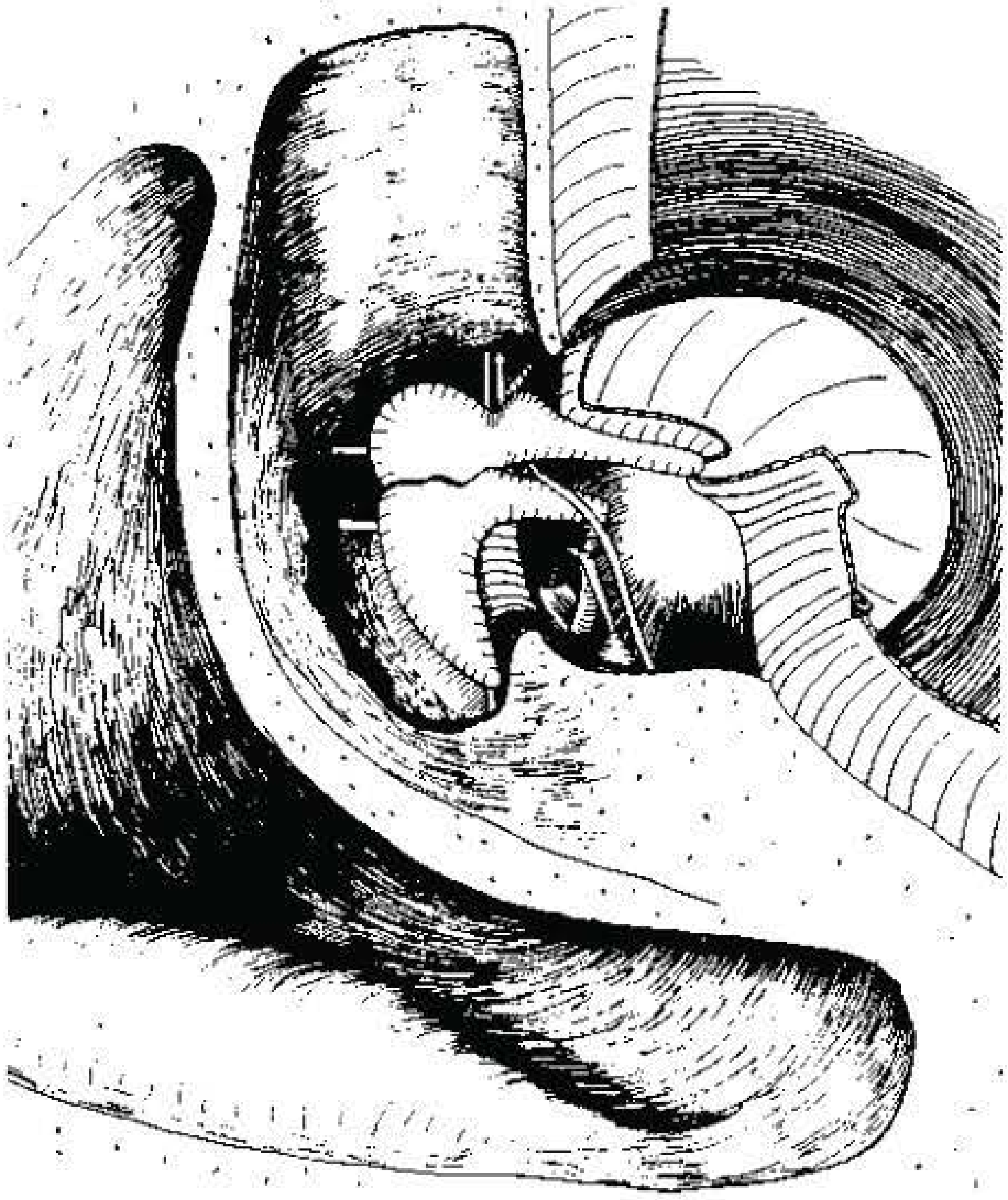


Fig. **46** **Widening of the ear canal with atticotomy and mastoidectomy, but without preservation of the bridge**

Farrior (1968) called this technique an anterior transcanal atticotympanotomy with posterior mastoidectomy. In the Farrior technique, the attic is open, not ventilated, and the mastoid cavity is therefore also not ventilated. Wullstein (1968) applied a similar technique in his transmeatal mastoidectomy.

Canal Wall–Down Mastoidectomies

The canal wall–down mastoidectomies include atticoantrotomy, Bondy's operation (1910), and conservative and classic radical mastoidectomies with total removal of the bony bridge (Figs. **8**, **9**,**12**,**13**, **22**, **23**, **27**, **28**).

The bridge can be totally or partly preserved, or moved posterolaterally, resulting in several intact bridge techniques, which are in fact modifications of canal wall–down techniques.

Modification of Canal Wall–Down Mastoidectomy

This modification is related to the preservation or partial preservation of the bony bridge, resulting in *intact bridge techniques* (Fig. **48**). In cases with resorption of the lateral attic wall, the bridge can be preserved, but it is displaced laterally and posteriorly (Fig. **49**). The bridge may in fact be further displaced laterally and posteriorly (Fig. **50**).

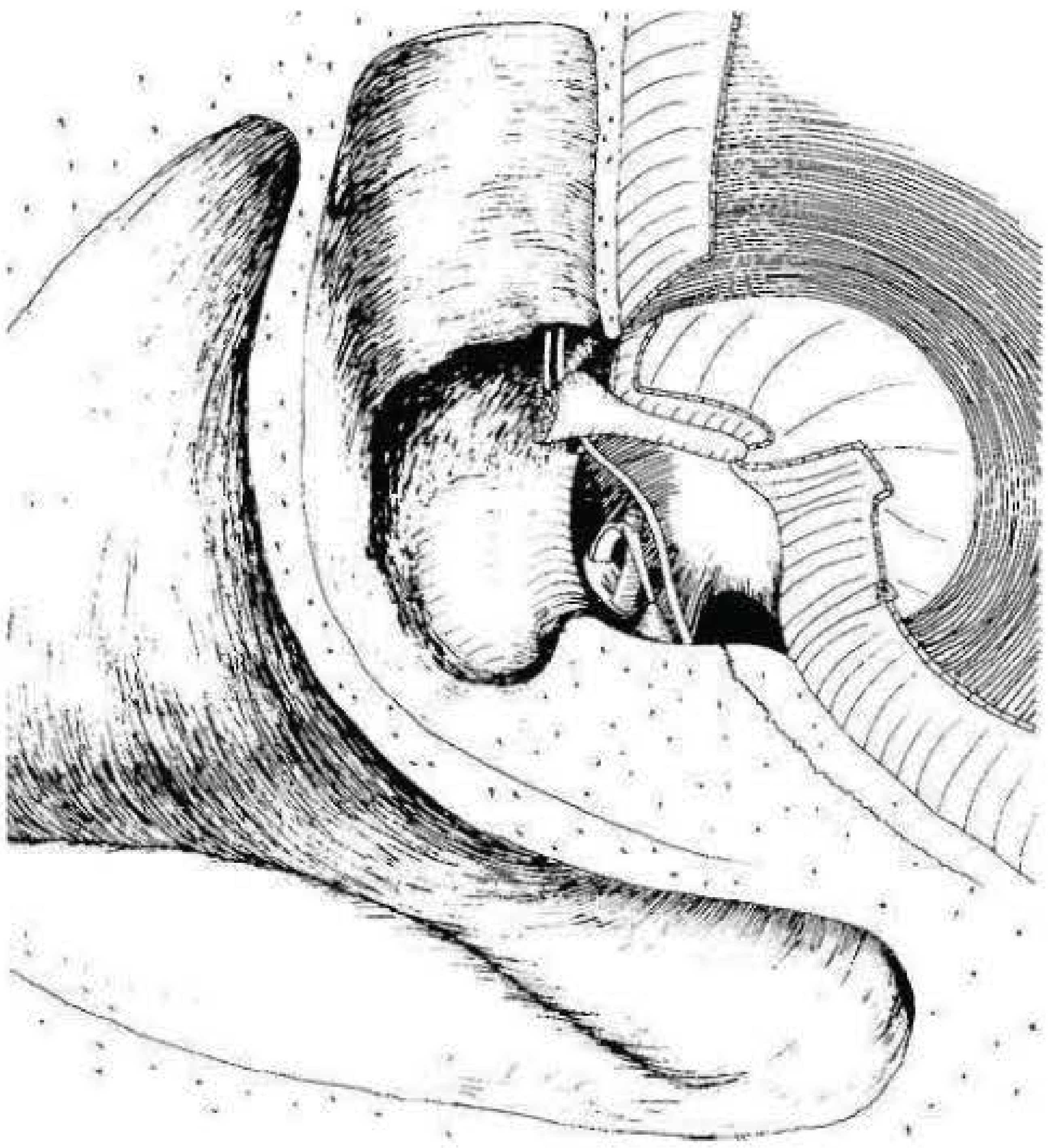


Fig. **47** **Widening of the ear canal, atticotomy, and mastoidectomy** in a situation without the incus and malleus head

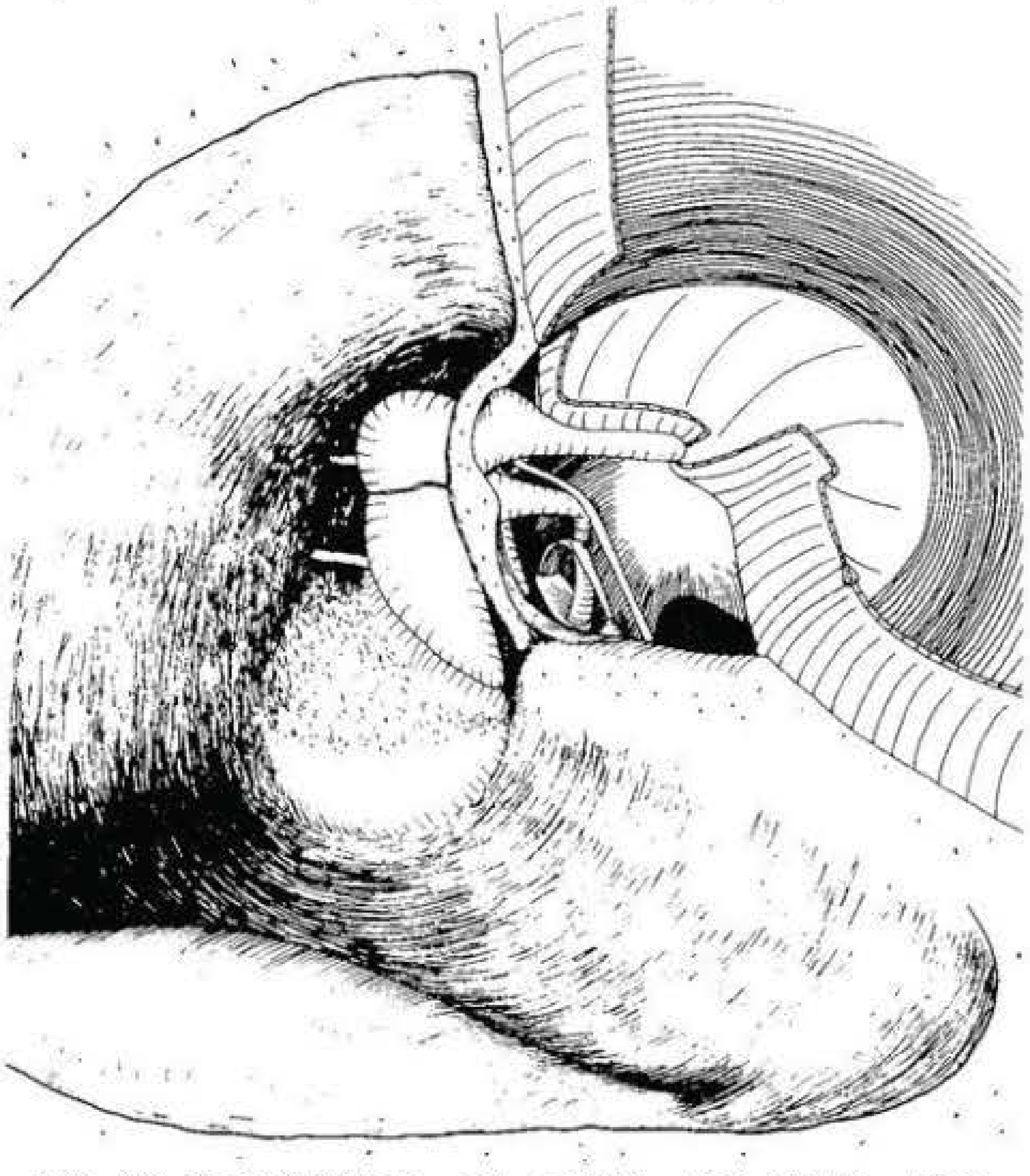


Fig. **48** **Modification of canal wall–down mastoidectomy,** with the preserved bridge in its normal position

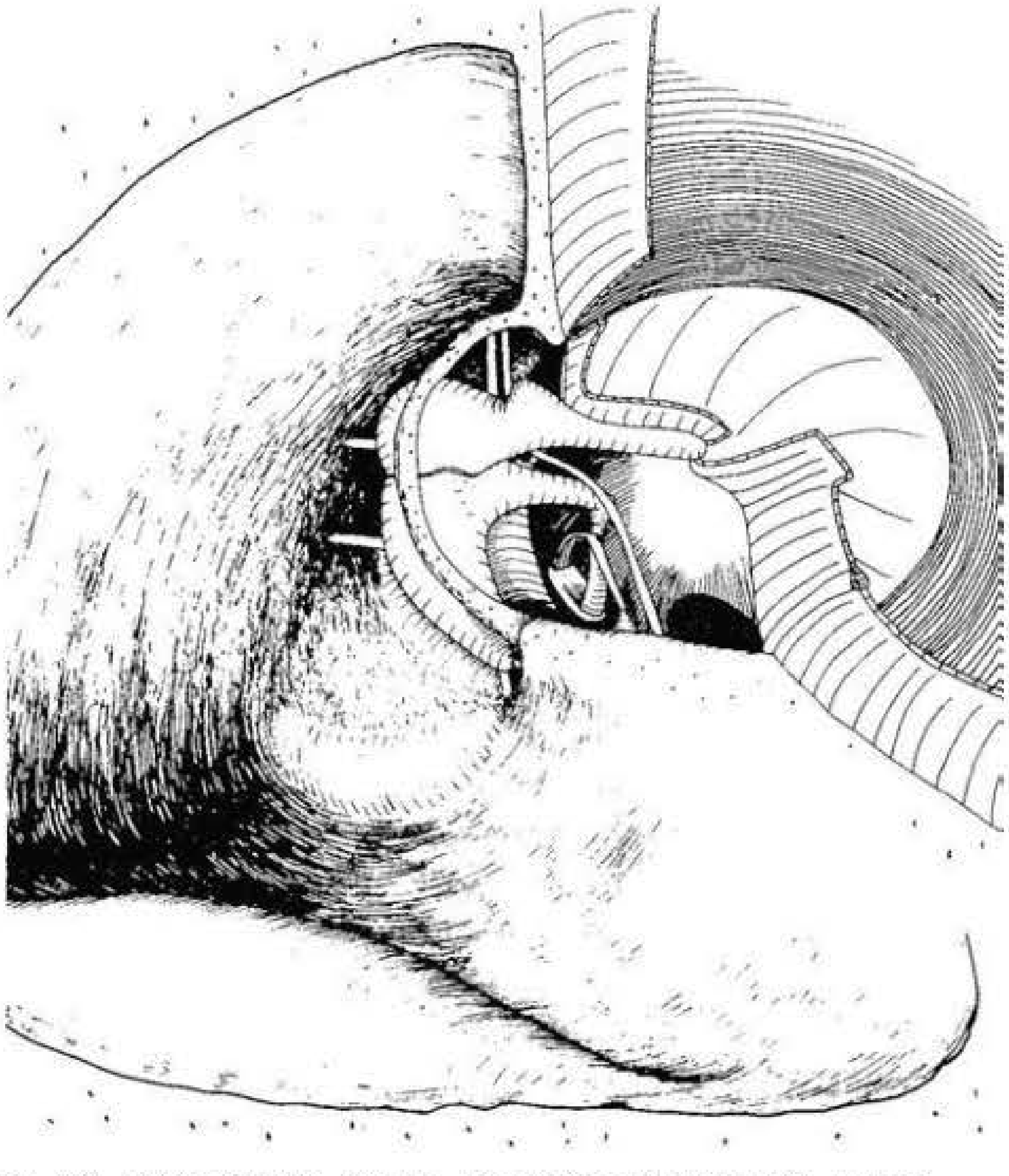


Fig. **49** **Canal wall–down mastoidectomy with preservation of the bridge** in a case with spontaneous erosion of the lateral attic wall, resulting in the bridge being displaced laterally and posteriorly

The bridge may be partly resorbed, or surgically removed either posteriorly (Fig. **51**) or anteriorly. In combination with various degrees of ossicular deficiency (e.g., missing incus but present malleus, or missing incus and malleus head) and various types of partial bridge removal, several variations are described.

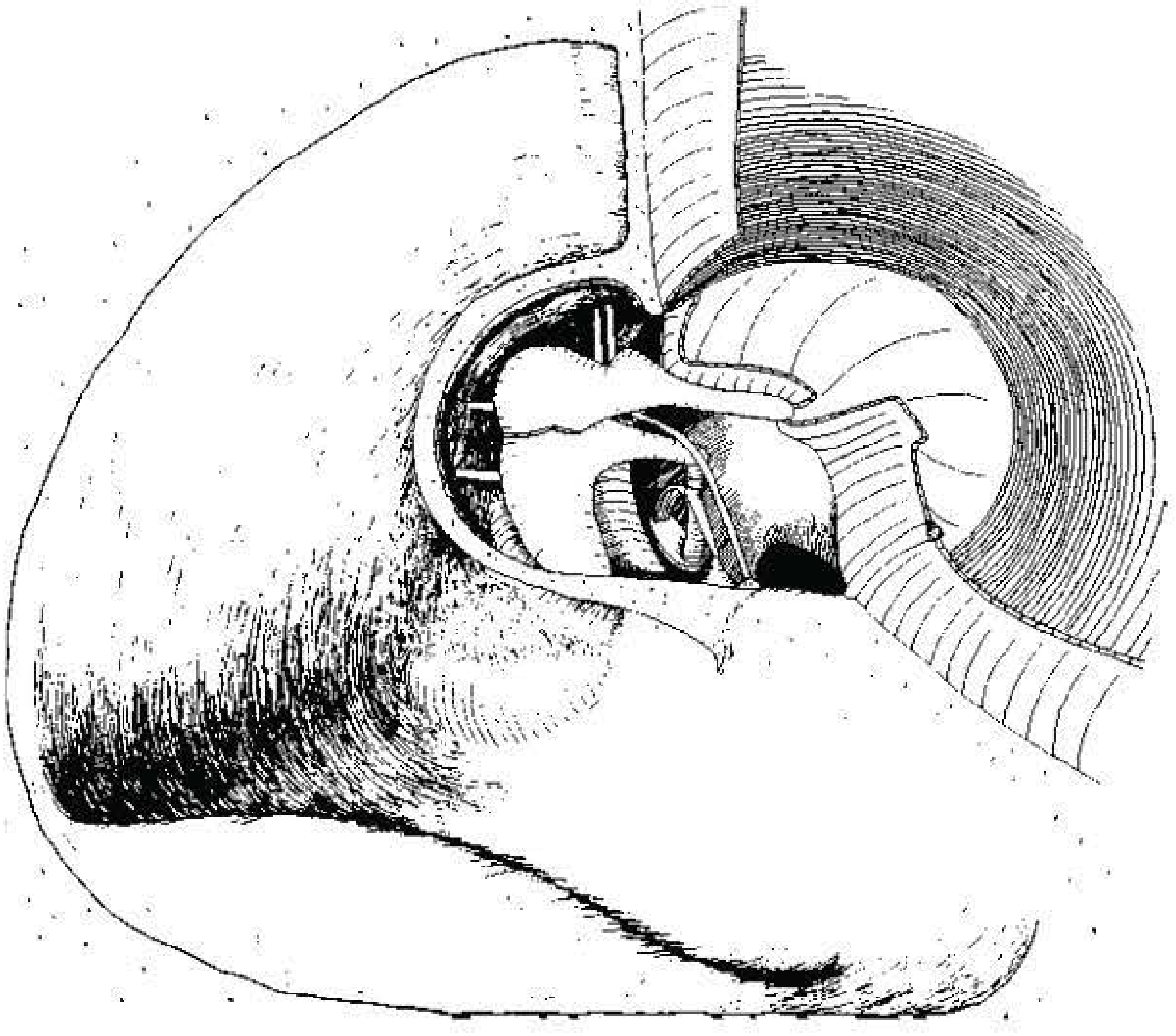


Fig. **50** **Canal wall–down mastoidectomy with preservation of the bridge,** which is displaced laterally and posteriorly in relation to the incus and malleus

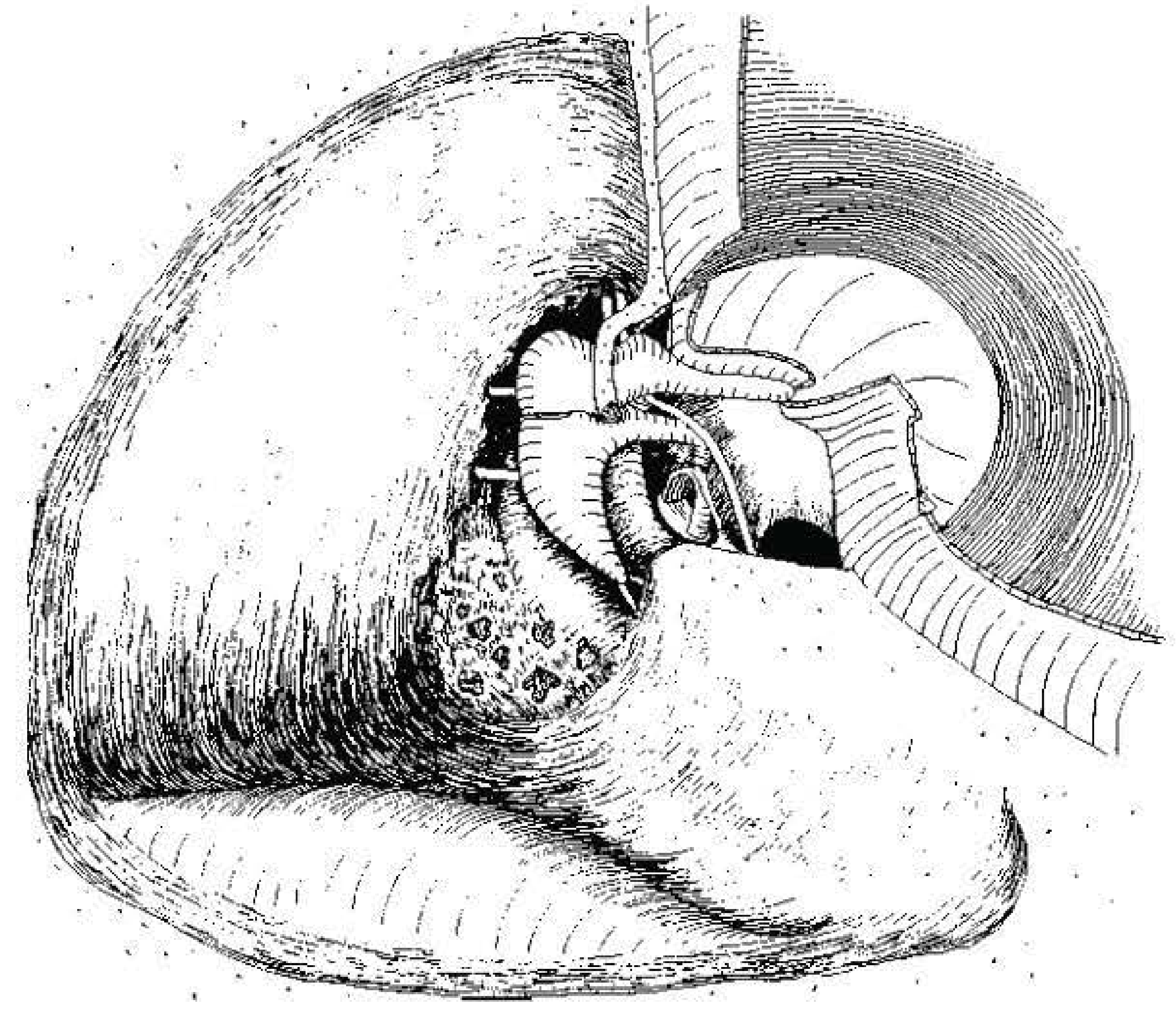


Fig. **51** **Canal wall–down mastoidectomy with partial preservation of the bridge** in a case with spontaneous resorption of the bridge

2 Anatomy

Surgical Anatomy of the Temporal Bone

The anatomy of the temporal bone is extremely complicated. It is thoroughly described in two excellent books, by Proctor (1989) and Anson & Donaldson (1992). In this chapter, only the anatomical landmarks necessary for mastoid surgery will be described. The illustrations (with the exception of Figs. **52** and **61**) show the anatomy as seen by the surgeon sitting beside the patient and operating on the right ear.

The anatomy of the external ear and its surrounding soft tissue are described in Volume 1.

The temporal bone is divided into: 1) The squamous part, with the zygomatic process and the mandibular fossa. 2) The mastoid part, with the mastoid process and the cortical bone posterior to it. 3) The tympanic part, forming most of the ear canal and extending between the tympanomastoid and the tympanosquamous sutures. 4) The petrous part, including the antrum, middle ear, inner ear, and petrous apex (Fig. **52**).

The Extracranial Surface of the Temporal Bone

After exposure of the mastoid process using the retroauricular approach (Fig. **25**) or the endaural approach (Fig. **24**), the *suprameatal spine* (Henle's spine), situated posterosuperiorly at the entrance of the ear canal, has to be located. The shape and position of the suprameatal spine varies. Anson and Donaldson (1992) describe four variants of the suprameatal spine, the styloid process and the tympanic bone:

Variant 1. The suprameatal spine is small and smoothly contoured. In these cases, the tympanic bone, forming the anterior wall of the external acoustic meatus, is a vertical plate, and the styloid process is very short (Fig. **53**). A straight external acoustic meatus provides the best visualization of the drum and tympanic cavity, and is the most favorable shape for tympanoplasty.

Variant 2. The suprameatal spine is a sharp and elongated crest (Fig. **54**). The deep tympanosquamous suture deludes a prominent anterior part of the tympanic bone, but the bone is a thin and straight plate that provides good access to the middle ear. The skin is difficult to elevate from the deep suture, and the

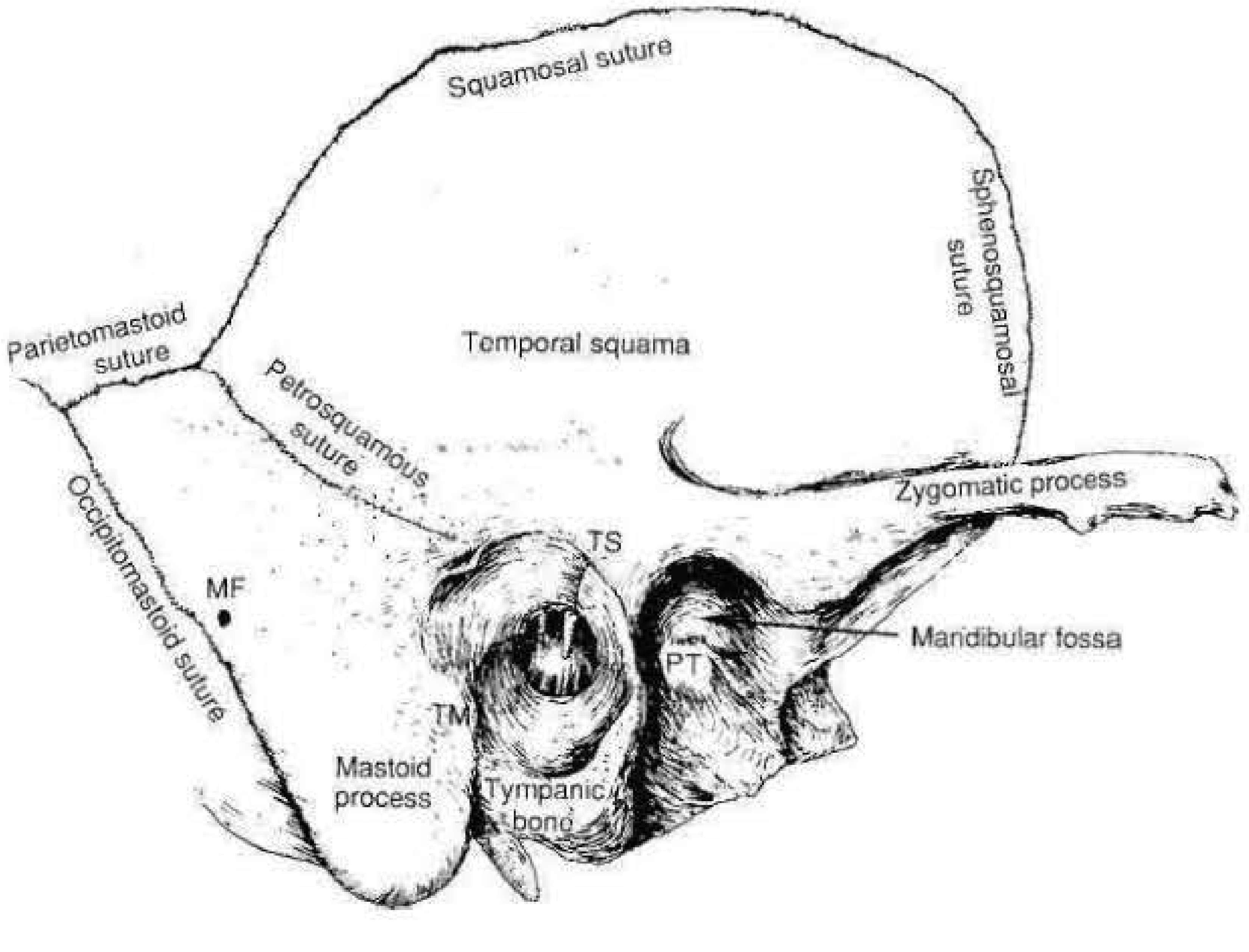


Fig. 52 **The extracranial surface of the right temporal bone** with its sutures seen in the normal position. It is divided into: 1) The squamous part with the large temporal squama, the zygomatic process, and the mandibular fossa. 2) The mastoid part, with the mastoid process and the mastoid cortex situated within the petrosquamous parietomastoid and occipitomastoid sutures. 3) The tympanic part, consisting of the tympanic bone, forming the external acoustic meatus between the tympanomastoid suture (TM) and the tympanosquamous suture (TS), continuing into the petrotympanic suture (PT) within the mandibular fossa. The mastoid foramen (MF) is the opening for the emissarium occipitale. 4) The petrosal part, involving the medial structures of the temporal bone, is not visible in this figure, except for the middle ear.

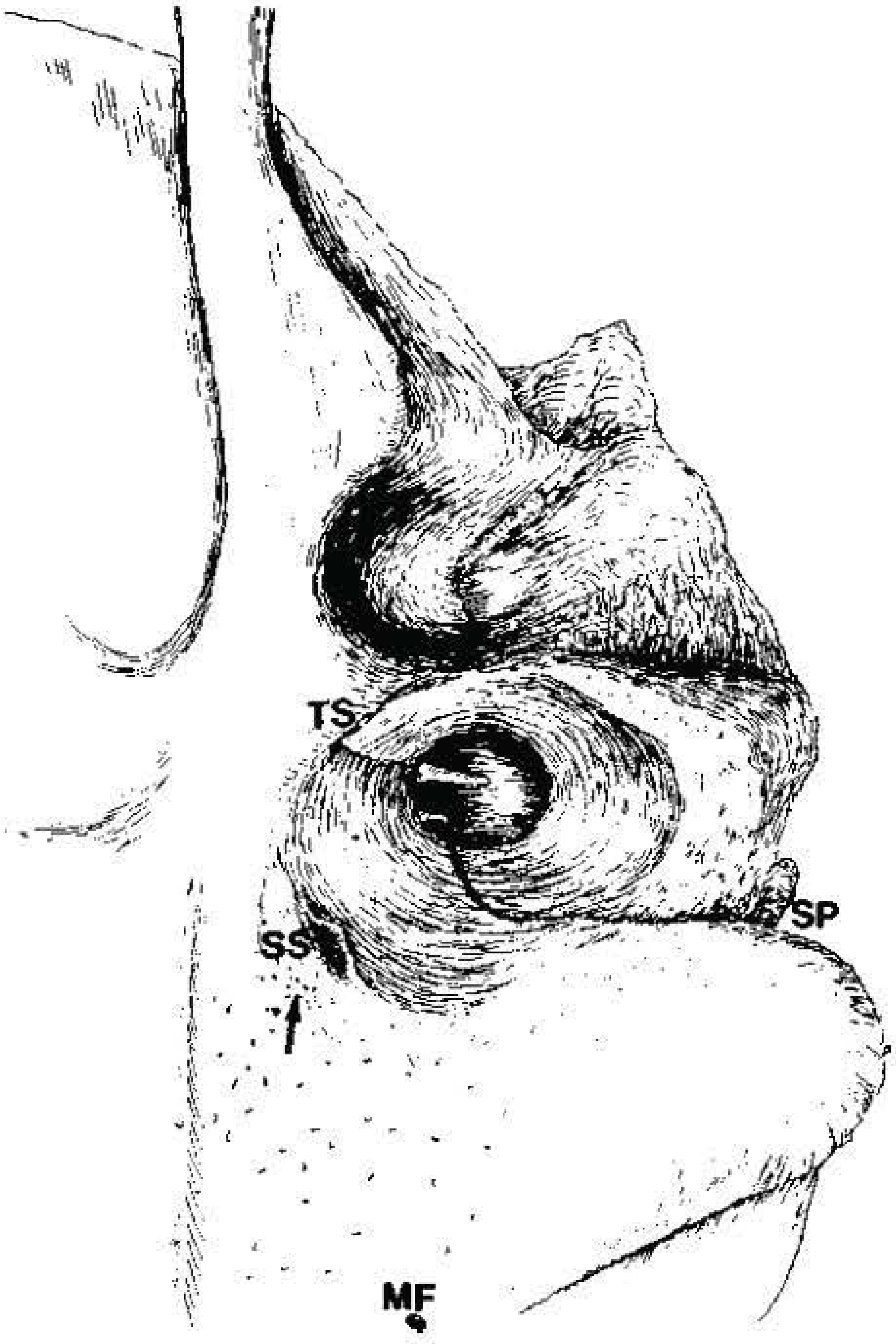


Fig. **53** **The surface of the temporal bone,** as seen by the surgeon sitting behind the patient. The suprameatal spine (SS) is small. The tympanic bone at the tympanosquamous suture (TS) is not prominent, and the anterior part of the tympanic bone is a vertical plate, allowing a relatively wide ear canal. The styloid process (SP) is very short. The course of the tympanomastoid suture posteriorly in the ear canal and the tympanosquamous suture superiorly (TS) is shown. MF: mastoid foramen, (MF), the cribriform area (arrow)

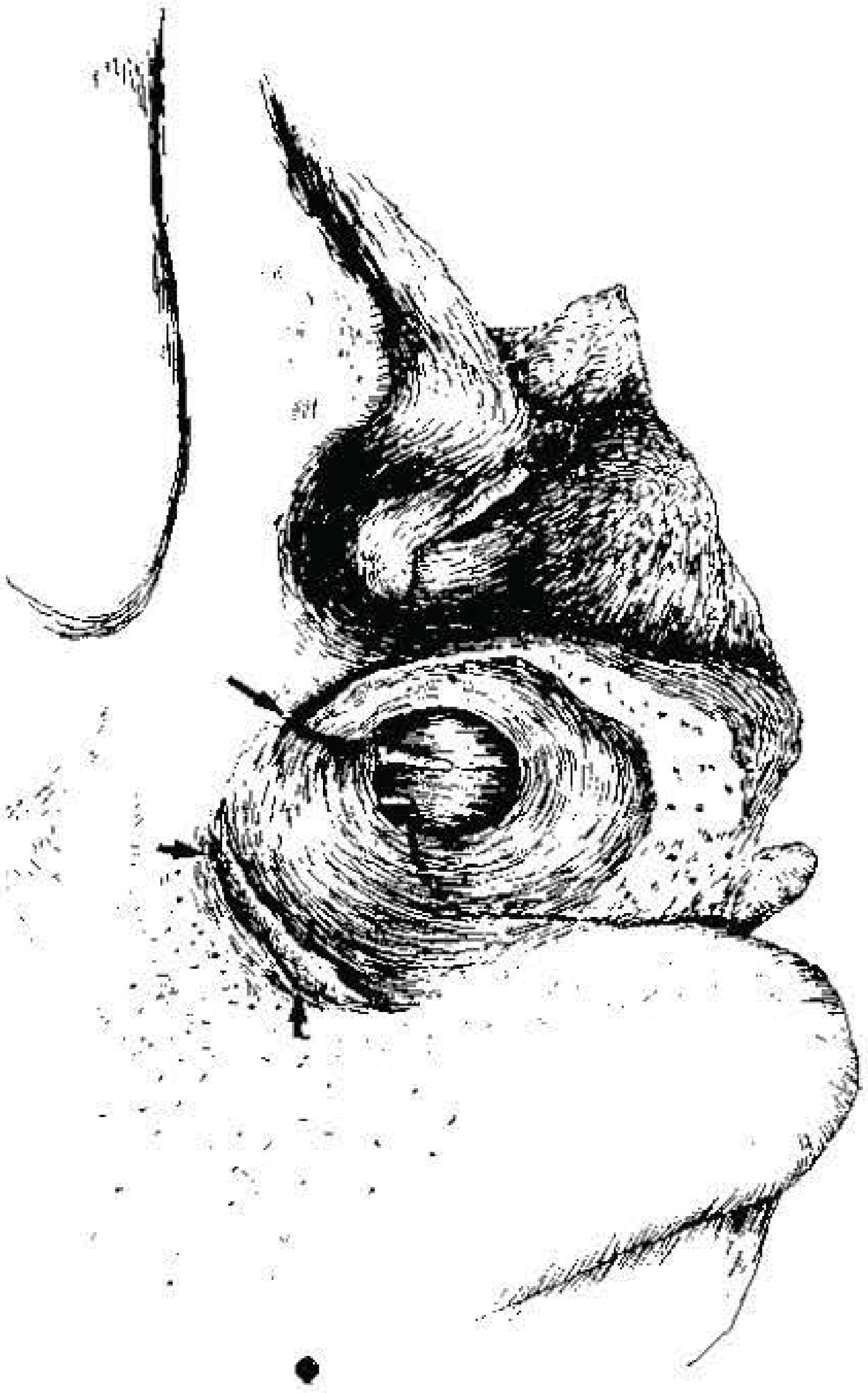


Fig. **54** **The surface of the temporal bone** The suprameatal spine is a sharp and elongated crest (small arrows). The tympanosquamous suture is deep (large arrow), but the anterior part of the tympanic bone is a thin, straight plate, allowing good visualization of the tymponomeatal angle. The styloid process is short. The suprameatal spine is placed posterosuperiorly in the cortex of the mastoid process, and is in fact only a small groove for entrance of the vessels coming from the antrum. The styloid process is long. The anterior part of the tympanic bone is thick and prominent

bone itself is not prominent. The styloid process is short.

Variant 3. The aperture for vessels lies somewhat superoposteriorly, close to the temporal line, and there is no true suprameatal crest, only a cone-shaped depression. The styloid process is relatively long (Fig. **55**). The anterior part of the tympanic bone is thick and prominent.

Variant 4. The suprameatal area is smooth, and there is no suprameatal crest. The external auditory meatus is oval in outline, and the tympanic part of the temporal bone, forming the anterior wall of the ear canal, is prominent. The styloid process is very long (Fig. **56**).

The *temporal line* is a horizontal ridge, continuing from the superior border of the zygomatic process posteriorly onto the mastoid cortex (Fig. **52**). The temporal line is not always evident. Sometimes it is a prominent sharp ridge (Figs. **53, 57**), sometimes a broad prominence (Fig. **55**), and in some other cases it is hardly recognizable (Figs. **54, 56**). It is safest to start drilling the mastoid cortex a few millimeters below the temporal line and gradually proceed towards it.

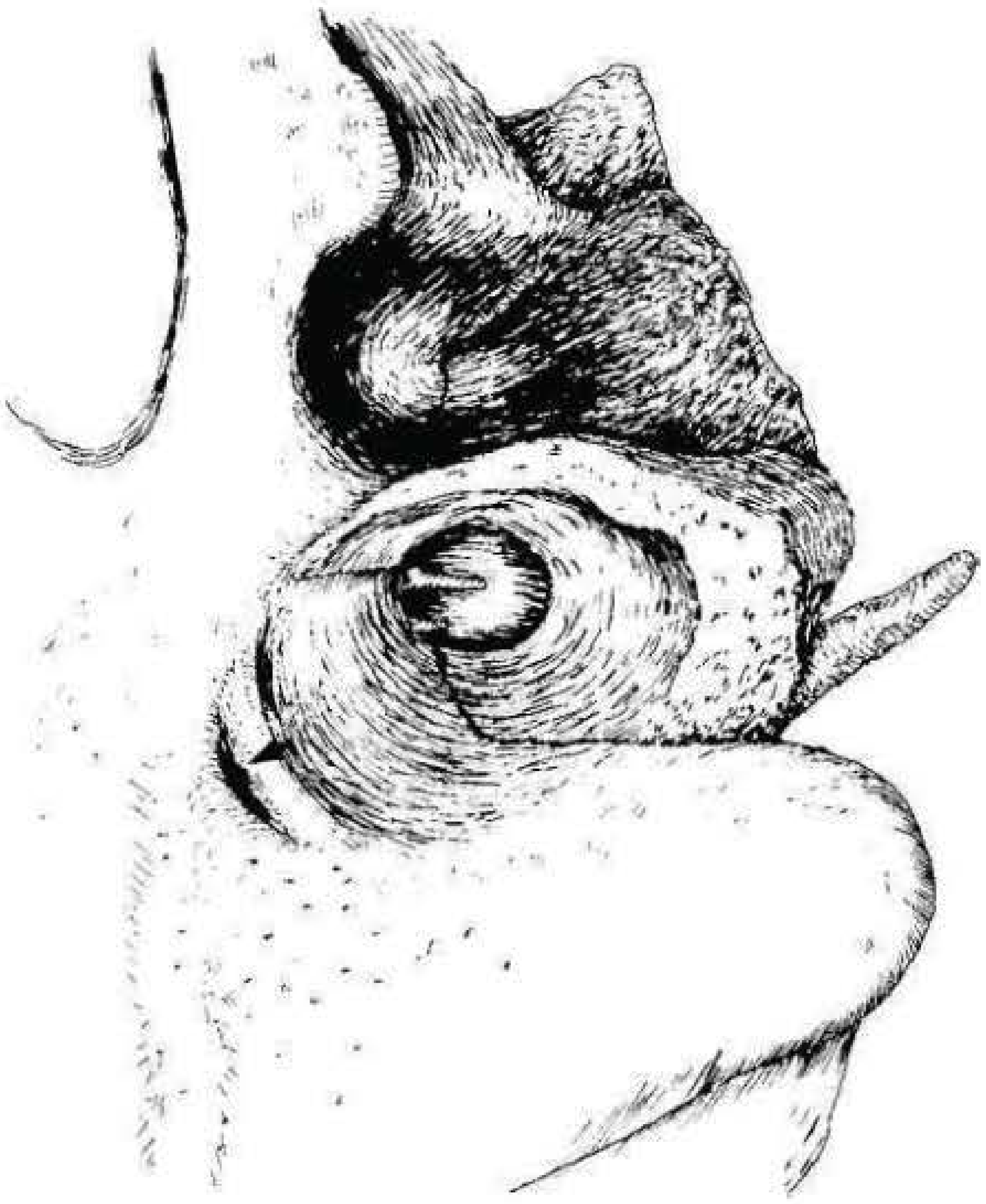


Fig. **55** **The surface of the temporal bone.** There is no true suprameatal crest, only a cone-shaped depression close to the temporal line (arrow). The styloid process is long, and the tympanic bone is thick and prominent

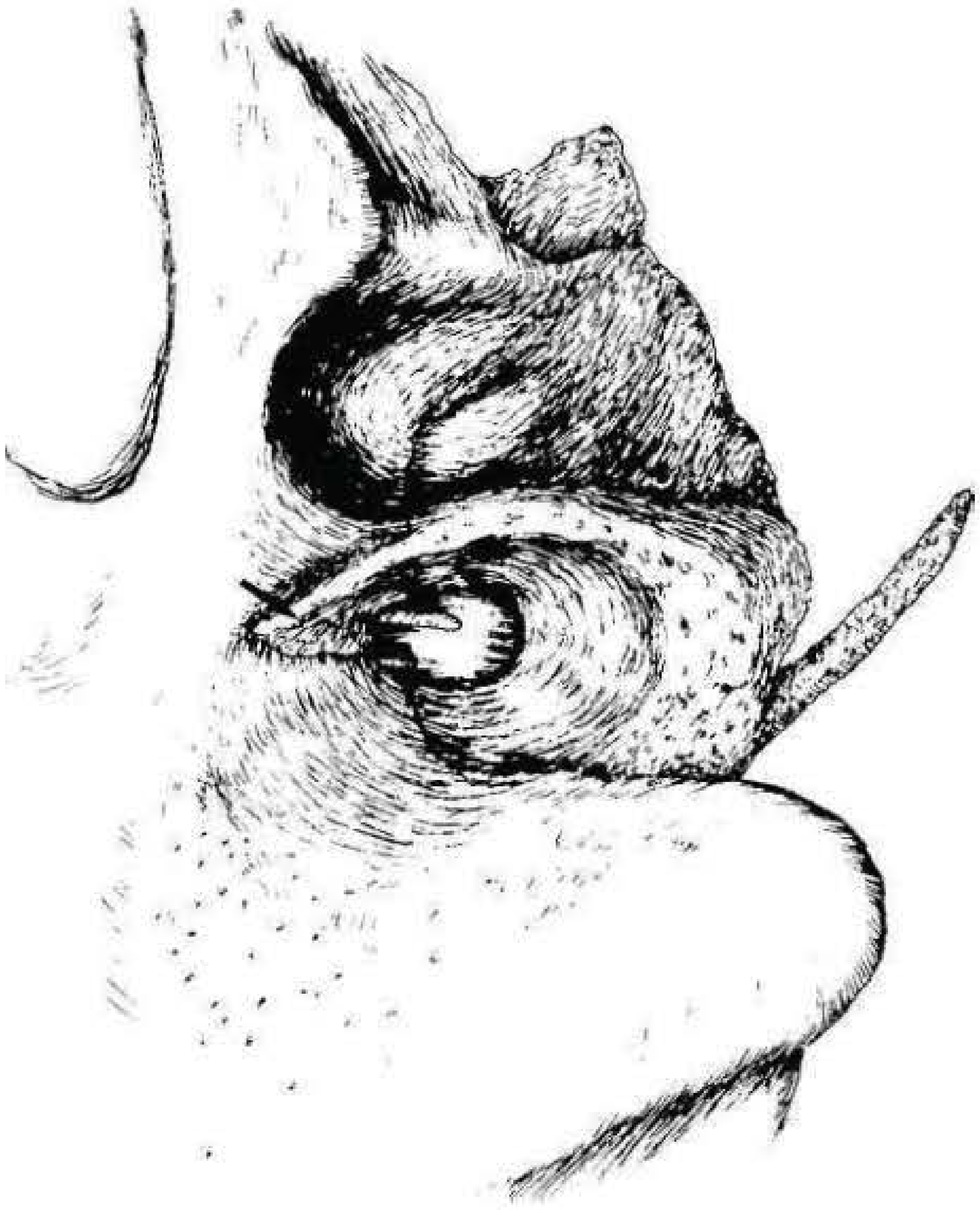


Fig. **56** **The surface of the temporal bone.** The suprameatal spine is not present. The anterior part of the tympanic bone is very prominent and thick (arrow). The ear canal is oval, the tympanosquamous suture is deep, and the styloid process is very long

Posterior to the suprameatal spine, a group of small holes in the mastoid cortex are occasionally seen, described as the cribriform area (Fig. **53**). Small vessels pass through these foramina to the mucosa of the underlying antrum in infants, and it is here that a subperiosteal abscess forms in cases of acute coalescent mastoiditis. The cribriform area lies within *Macewen's triangle* (Fig. **57**), an imaginary triangle defined by three lines. The first line is the temporal line; the second is formed by the superior and posterior margins of the external bony meatus (this line goes through the suprameatal spine). The triangle is completed by a line drawn perpendicular to the first line and tangential to the second. Macewen's triangle roughly defines the mastoid antrum deep to the cortex.

Posteriorly, alongside the occipitomastoid suture, the mastoid foramen is visible, and this is the opening of the *emissarium occipitale (Santorini)* (the occipital emissary vein) connecting the veins of the occipital region with the sigmoid sinus (Fig. **52**).

The *roof* of the bony ear canal is an important landmark, and should be visualized in any type of mastoidectomy except simple mastoidectomy. The

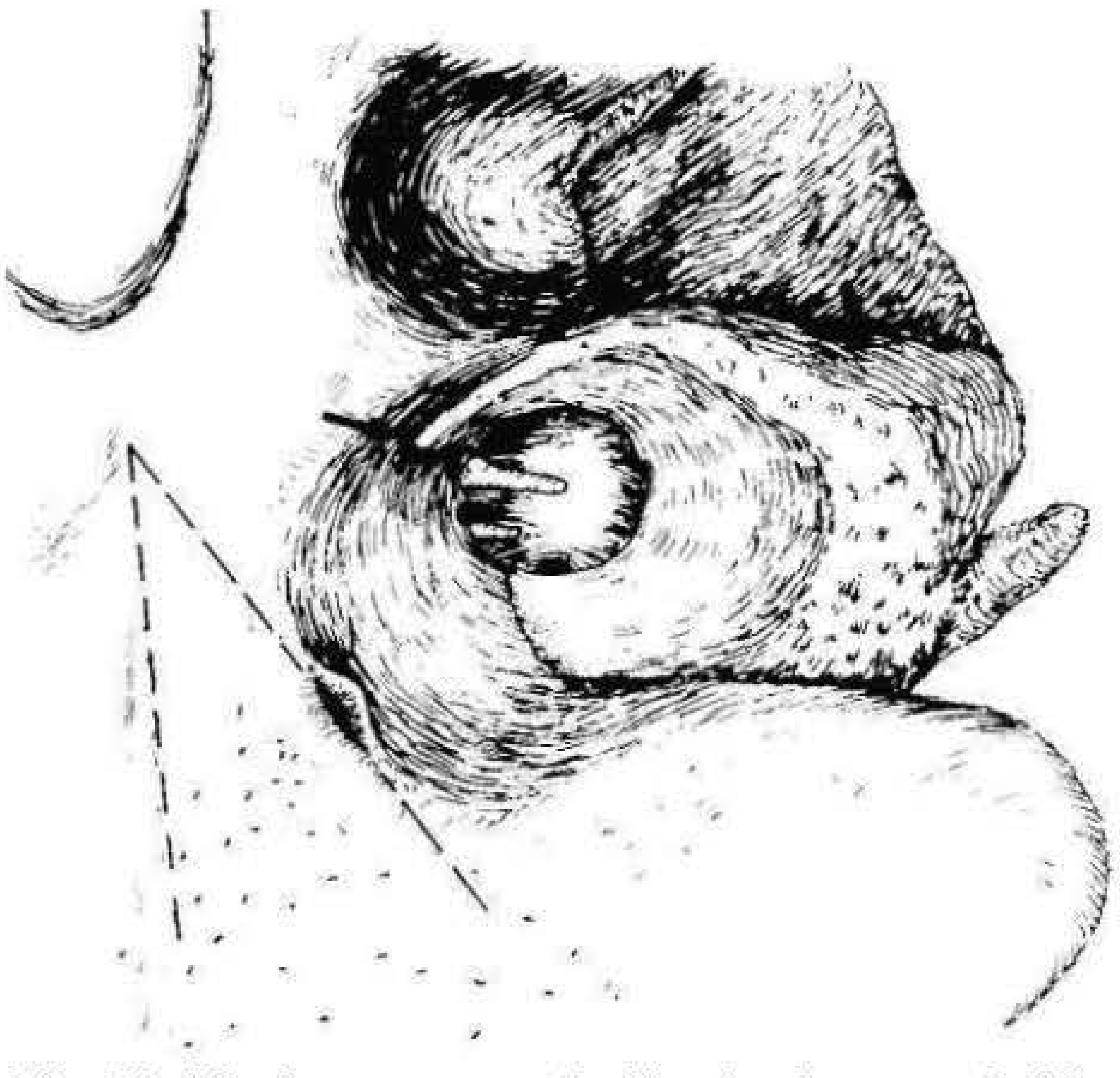


Fig. **57** **The bony ear canal,** with a barely recognizable tympanosquamous suture (arrow). The temporal line is a sharp ridge, and Macewen's triangle is indicated (dashed line)

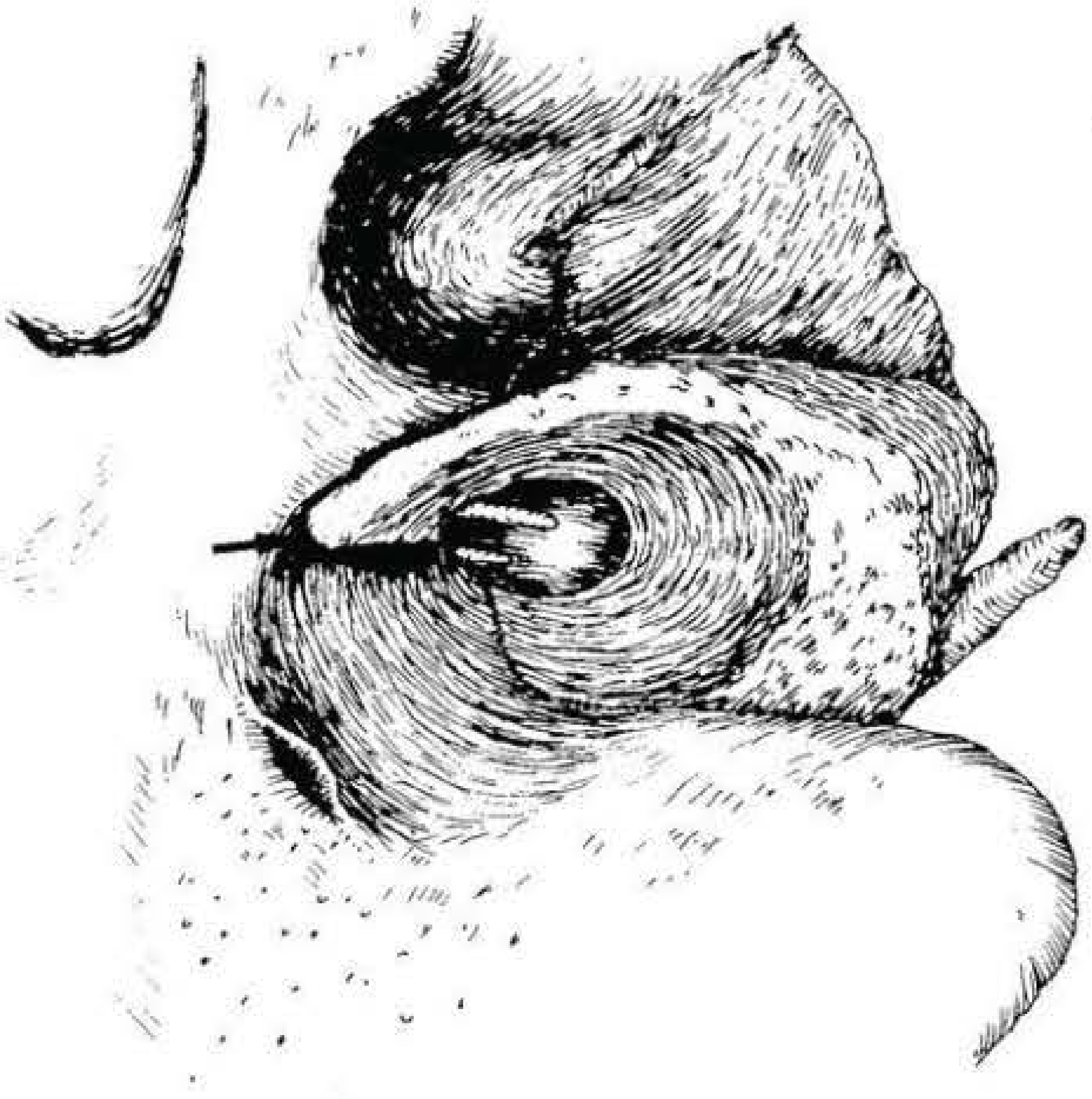


Fig. **58** **The bony ear canal,** with a deep tympanosquamous suture (arrow) and a prominent notch on the anterior part of the tympanic bone

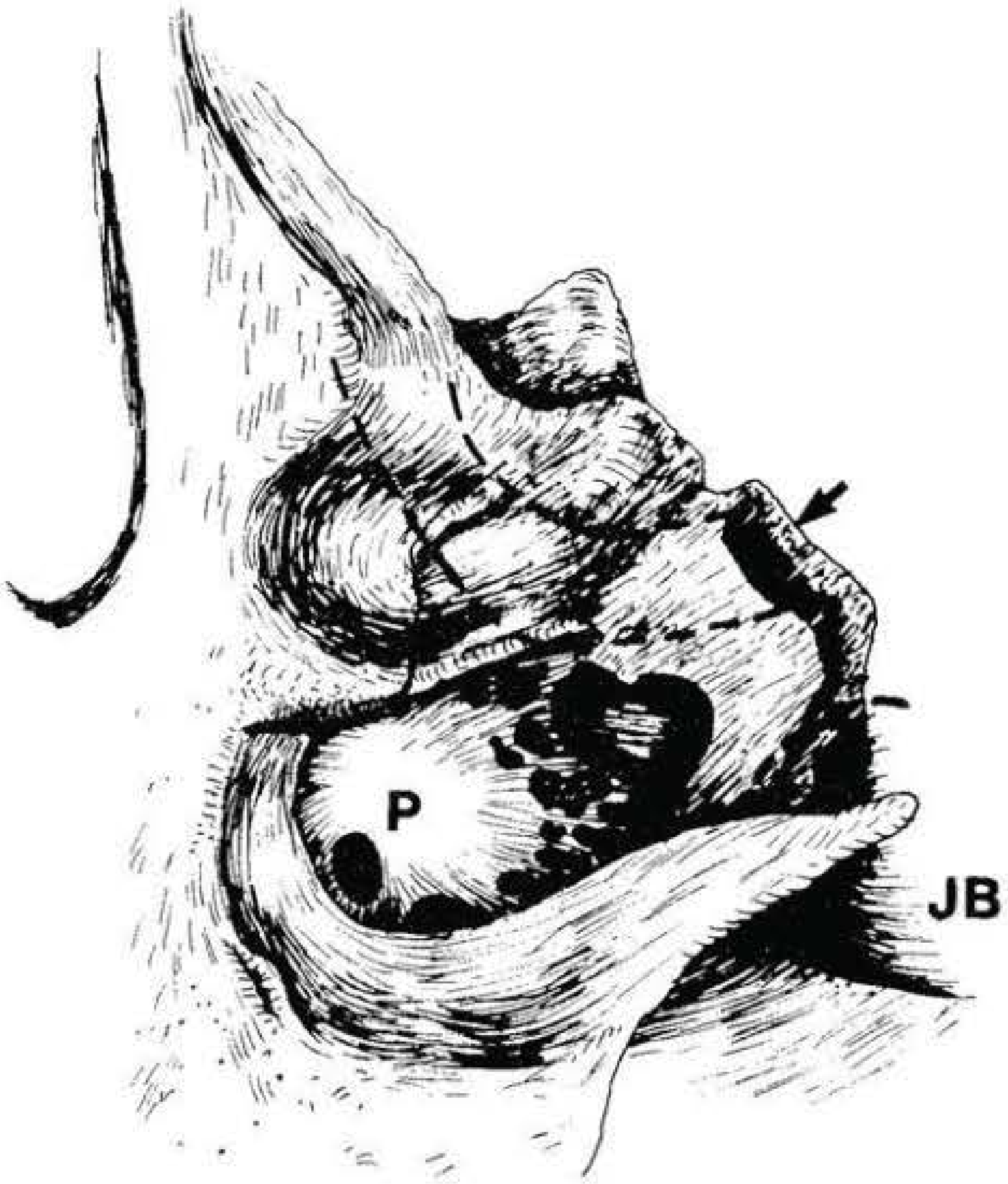


Fig. **59** **The hypotympanum.** The tympanic bone has been removed to illustrate anatomic relationships in the hypotympanum. P: the promontory, with the oval window superiorly, the round window niche posteriorly, and the hypotympanic cells inferiorly. JB: the jugular bulb fossa; the entrance of the carotid artery (arrow) and its course through the temporal bone (dashed lines)

canal skin should be carefully elevated, and the *tympanosquamous suture* should be located at the 12-o'clock position and exposed. The skin is firmly attached at the suture by fibrous tissue, which should be cut with a sickle knife in order to expose the entire suture. The size of the tympanosquamous suture varies from a small, barely recognizable fissure (Fig. **57**) to a deep notch, hampering the view of the Shrapnell's membrane region (Fig. **58**). Any irregular bone in the superior part of the ear canal should be drilled away in any type of mastoidectomy. A deep tympanosquamousal suture can also be described as a fissure.

The *floor* of the ear canal is formed by the tympanic bone, and should also be visualized before the mastoidectomy, at least as far as the *tympanomastoid suture,* which starts medially at the bony annulus at the 9-o'clock position and continues inferolaterally towards the apex of the mastoid process (Figs. **53, 58**). Sometimes extensive drilling of the tympanic bone needs to be performed in order to visualize the lower part of the posterior tympanum or the hypotympanum in cases of cholesteatoma or glomus tumor. Removal of the tympanic bone between the two fissures gives an excellent view of the entire hypotympanum and carotid canal (Fig. **59**).

The Mastoid Process—The Mastoidectomy

After the temporal line, the suprameatal spine, Macewen's triangle, the roof and floor of the ear canal, the tympanosquamous and the tympanomastoid sutures, and the tip of the mastoid process (Figs. **52, 53**) have been identified, the cortical bone is removed from the surface using a large cuttting burr, starting behind the suprameatal spine within Macewen's triangle. After wide cortical bone removal, exenteration of the lateral mastoid air cells is performed (Fig. **60**). The anatomy of the lateral part of the mastoid process varies widely in relation to the degree of pneumatization, which can be almost nonexistent, with no cells at all, or extensive, with complete pneumatization of the mastoid process, thin cortical bone, and many large and small cells extending subcortically posterior to the sigmoid sinus. Toward the tip of the mastoid process, the cells are usually larger (Fig. **60**).

Middle Cranial Fossa Dural Plate

Superiorly, the middle cranial fossa dura plate has to be located. This is achieved by drilling superiorly in the mastoid process, toward the temporal line (Fig. **60**). The mastoid air cells superiorly lie just under the cortical bone, and end in a solid bony plate. This plate continues medially (Fig. **61**). When the bone at the middle cranial fossa dura plate is thinned, the dura becomes visible, a pinkish color initially showing through the thin bony plate, followed by the whitish color of the dura itself or by bleeding from small dural vessels. The pinkish color is due to the vascularization of the dura.

Laterally, the middle fossa dura plate is large. It extends from the zygomatic region anteriorly to the sinodural angle and the superior petrosal sinus posteriorly (Fig. **61**). Because the superior petrosal sinus runs in an anteromedial direction, the area of the middle fossa dura plate diminishes medially toward the labyrinth.

The middle fossa dura plate is the roof, or tegmen, of the pneumatized spaces of the temporal bone. The tegmen is divided into the *tegmen mastoidei,* the most lateral part; the *tegmen antri* at the level of the mastoid antrum; and the *tegmen tympani* at the level of the epitympanum, extending medially as far as the superior semicircular canal and the epitympanic recess anteriorly (Fig. **61**).

There is some disagreement about the nomenclature for the tegmina. Anson and Donaldson (1992) use only the term *tegmen tympani.* Proctor (1989) uses both the terms *tegmen tympani* and *tegmen antri,* and as well as these Proctor uses the terms *squamosal tegmen* for the area lateral to the petrosquamous lamina (Körner's septum), and *petrosal tegmen* for the area medial to it. Some surgeons use the term *tegmen tympani* for the entire middle fossa dural plate while others reserve the term for its medial part. The present author believes that this large and surgically important area of middle fossa dura plate should be topographically subdivided into three parts, allowing for more precise description of the pathology and surgical techniques associated with it, and therefore suggests the terms *tegmen mastoidei* for the most lateral part; *tegmen antri* for the middle part, forming the roof of the mastoid antrum; and *tegmen tympani* for the most medial part, forming the roof of the epitympanum and pretympanic recess (Fig. **63**).

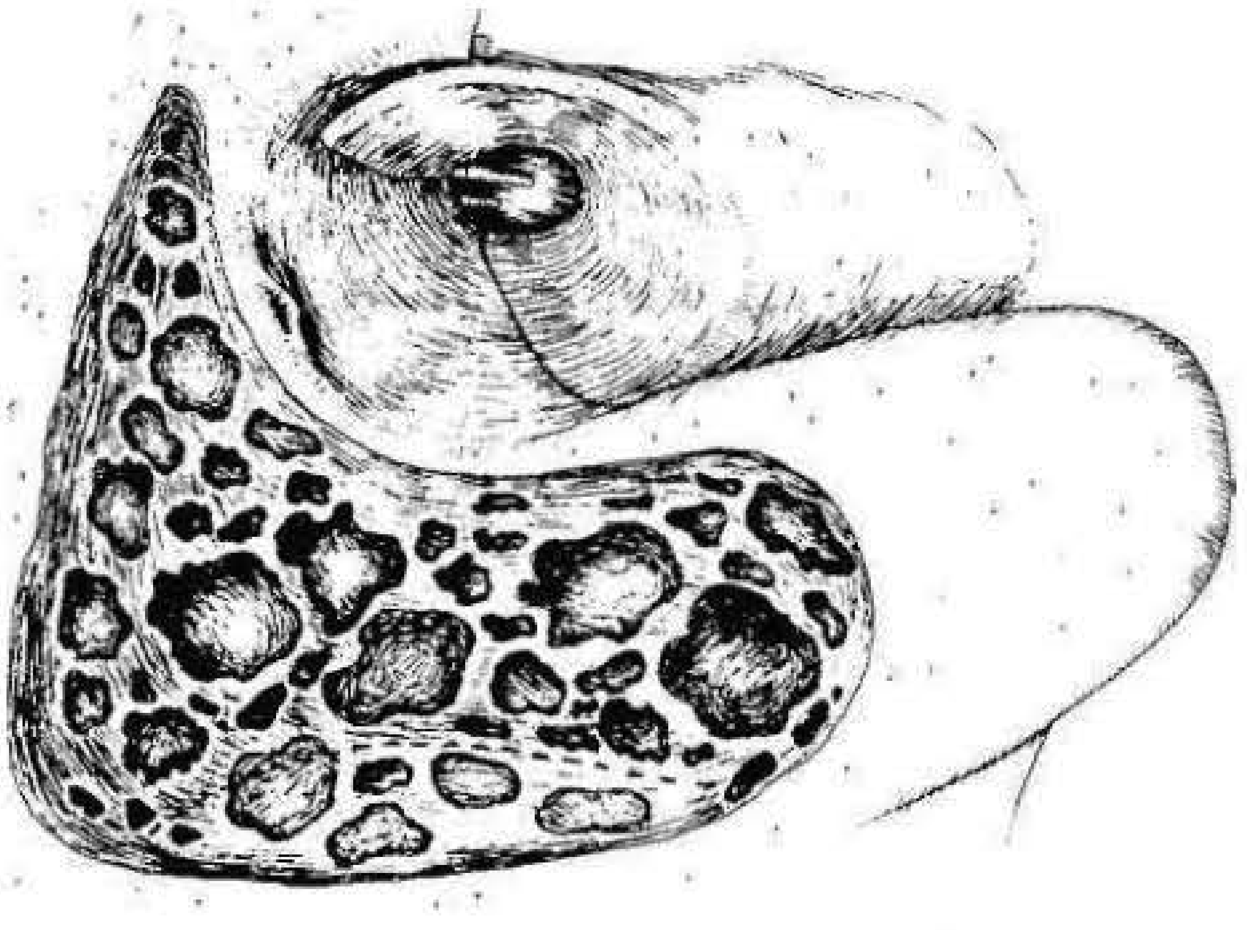


Fig. **60** **The subcortical lateral region of the mastoid process** in a case of extensive pneumatization, with large and small air cells occupying hte subcortical space of the entire mastoid process. The cortical bone is relatively thin. Superiorly, the middle fossa dura plate is indicated, and posteriorly, the approximate position of the lateral sinus is indicated by dashed line

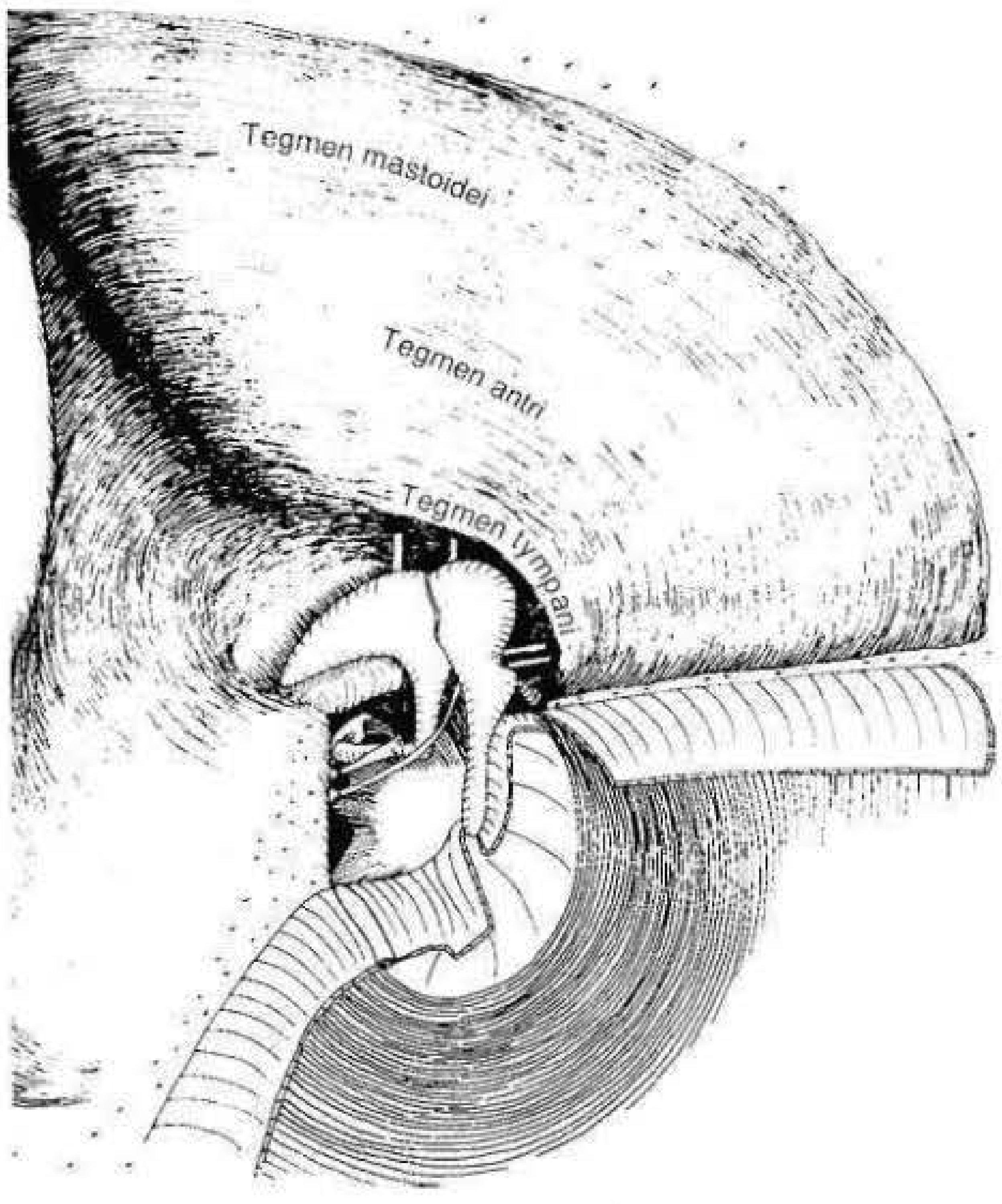


Fig. **61** **Division of the middle fossa dura plate** into the tegmen mastoidei, tegmen antri, and tegmen tympani in a large canal wall–down mastoidectomy. The sinodural angle and sigmoid sinus are shown (infero-superior view seen in the normal position)

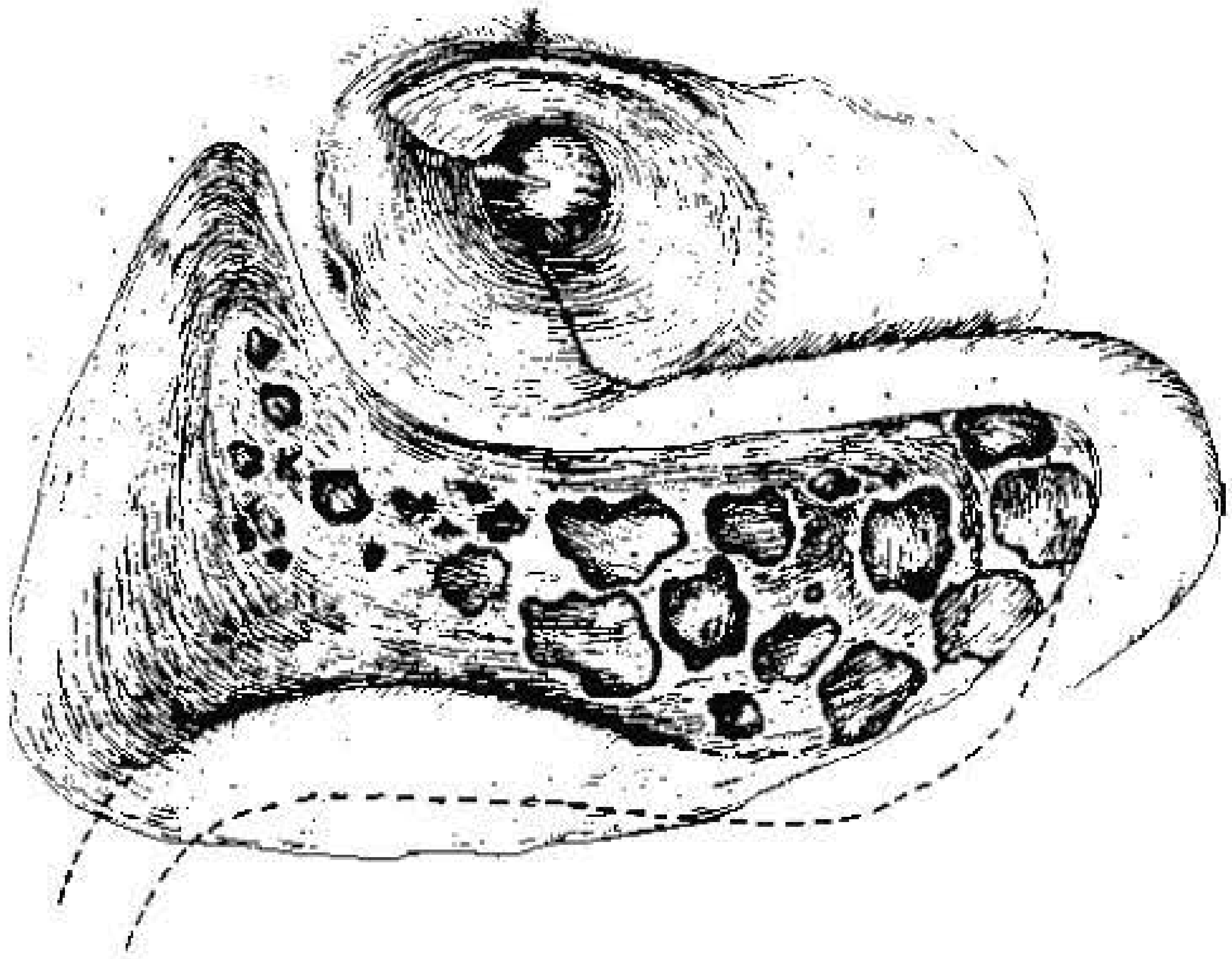


Fig. **62** **Cortical mastoidectomy**, with exenteration of the lateral mastoid air cells. There are large mastoid cells at the tip of the mastoid process, lateral to the sigmoid sinus. Superiorly, the mastoid cells are removed until Körner's septum (K) is reached and the middle fossa dura plate is exposed. Posteriorly, the most lateral part of the sigmoid sinus is exposed, and its further course towards the mastoid tip under the facial nerve is indicated

The Sigmoid Sinus

The posterior limit of the standard mastoid cavity is the sigmoid sinus, or lateral sinus. It is a continuation of the transverse sinus, and passes through the deep part of the mastoid process, under the facial nerve, toward the jugular bulb. In a well-pneumatized mastoid process, the lateral aspect of the sigmoid sinus is covered by mastoid air cells (Fig. **60**). After removal of these cells, a slightly bluish discoloration of a smooth bony plate can be seen (Fig. **62**). With further thinning of the bone over the sinus, it becomes increasingly blue. The sigmoid sinus usually lies a few millimeters deep to the cortex of the mastoid process. The posterosuperior part of the sigmoid sinus is at the most superficial level (Fig. **63**). Inferiorly, the sinus lies gradually deeper, making an anterior curve and crossing the tip of the mastoid process at a level deep to the digastric crest. Adjacent to the vertical portion of the facial nerve, before forming the jugular bulb, the sigmoid sinus lies deepest (Fig. **64**).

The anatomy of the sigmoid sinus varies. In relation to the ear canal, it can be positioned either anteriorly or posteriorly. Some investigators have found that the anteriorly positioned sinus is more common in ears with poor pneumatization (Heermann and Riehm 1961). We suspected the same tendency, but after measuring temporal bones, there was no significant correlation between the distance from the sigmoid sinus to the ear canal and the degree of pneumatization (Turgut and Tos 1992a).

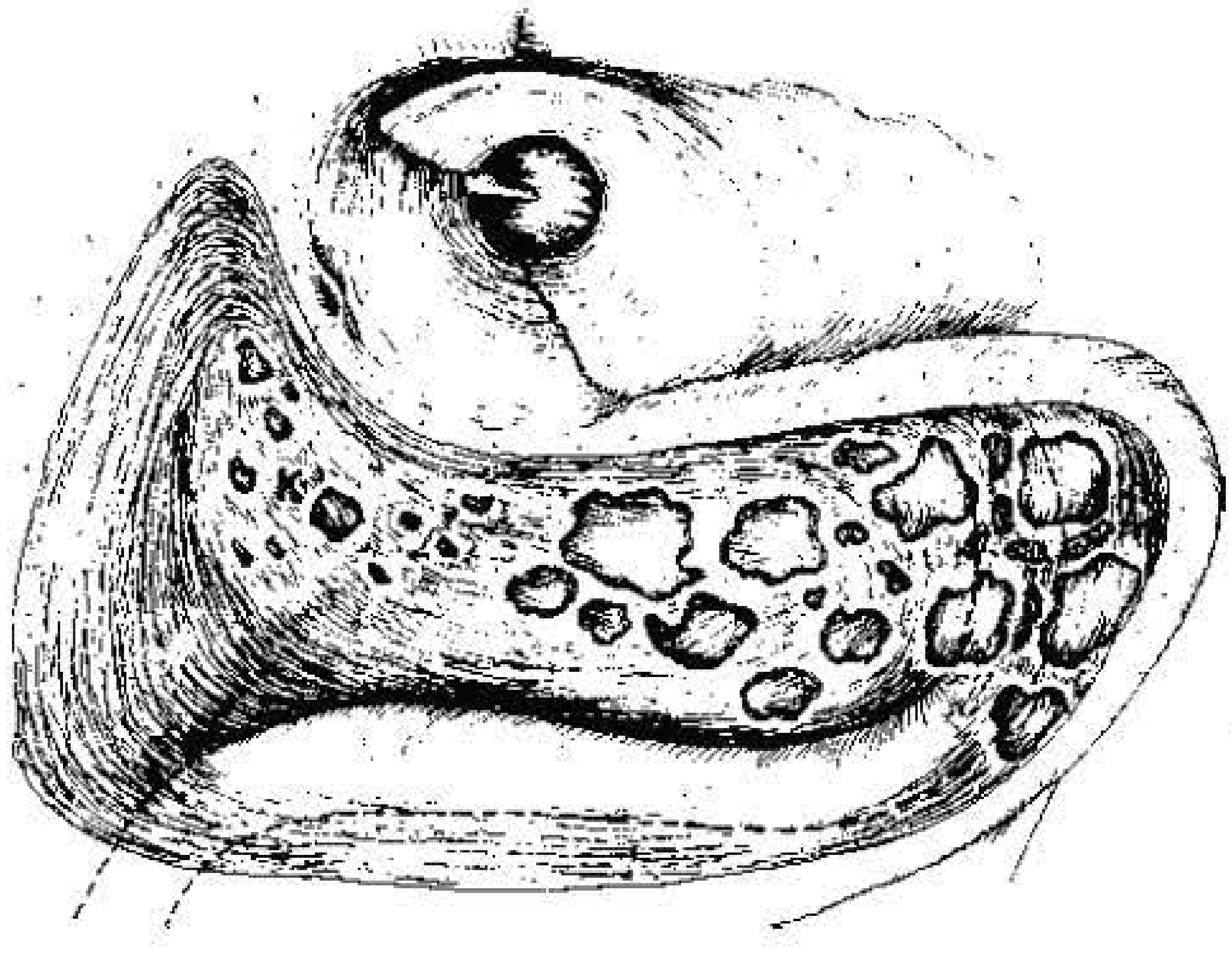


Fig. **63** **Cortical mastoidectomy**, with further exposure of the sigmoid sinus and the middle fossa dura plate and exenteration of the air cells as far as Körner's septum (K). At the tip of the mastoid, there are large air cells lying lateral to the sigmoid sinus

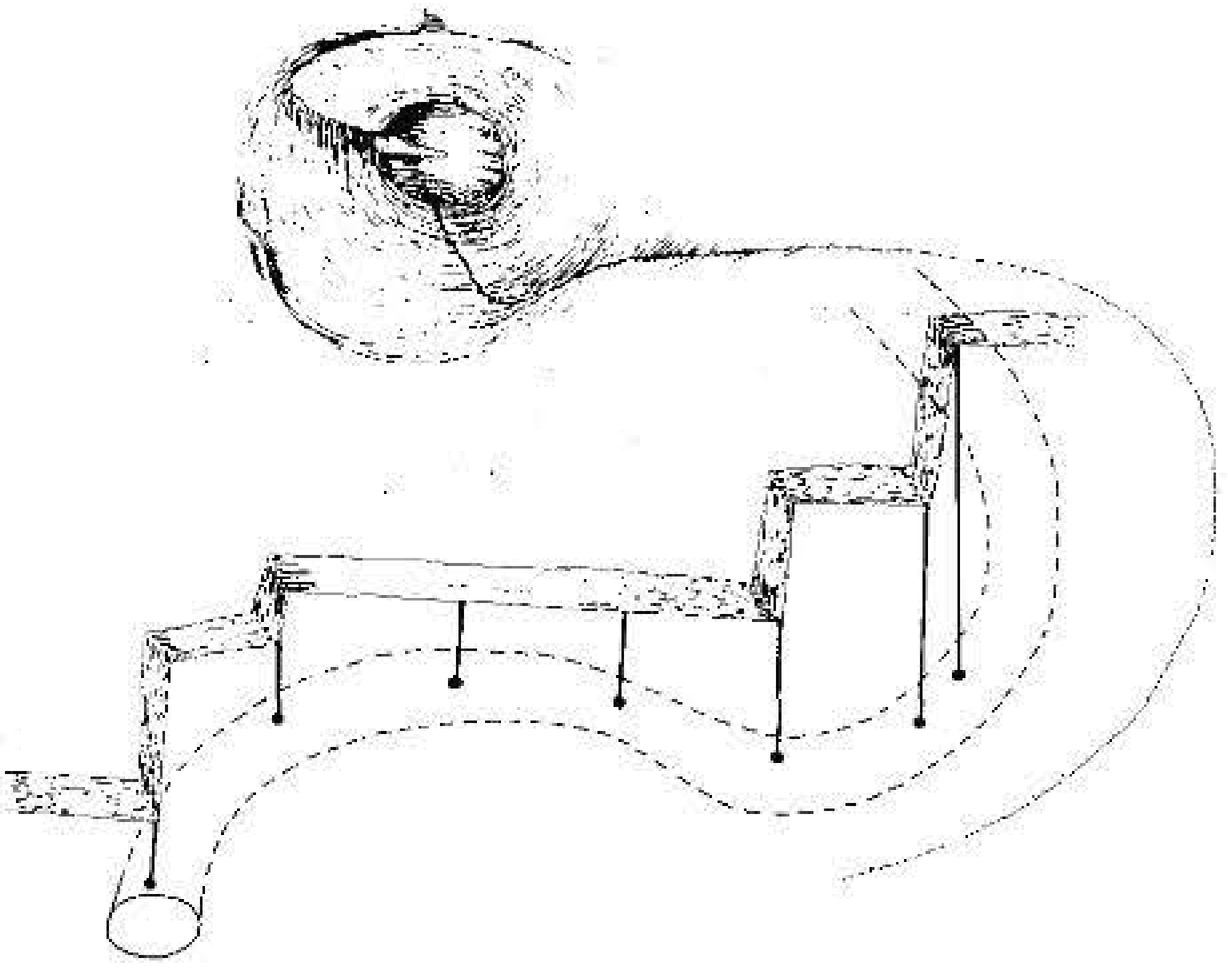


Fig. **64** **The position of the sigmoid sinus in relation to the mastoid cortex** (schematic). The most superficial position of the sinus is at its posterosuperior part. Toward the tip of the mastoid process, the sinus lies considerably deeper. Under the facial nerve and toward the jugular bulb, it is at its deepest

The Sinodural Angle

The sinodural angle is the angle between the middle fossa and posterior fossa dura plates and the superior part of the sigmoid sinus (Fig. **61**). In a well-pneumatized ear, small air cells usually occupy the sinodural angle, and should be removed or opened in a mastoidectomy. Sometimes it is necessary to drill deep down into the angle, exposing the superior petrosal sinus (Figs. **65, 66**). Laterally in this angle within the mastoid cortex, the *emissarium mastoideum (Citelli)* is located. This emissary vein connects the sigmoid sinus with the veins draining the middle fossa dura and the temporal squama. The veins may lead to troublesome venous bleeding during the drilling of the cortical bone in the most lateral part of the sinodural angle. The sinodural angle is usually deep. In the depths of the angle, the superior petrosal sinus is located (Fig. **66**). The superior petrosal sinus enters the sigmoid sinus on its medial surface, and runs in a bony sulcus along the edge of pars petrosa, dividing the middle fossa dura plate from the posterior fossa dura plate (Fig. **67**). It runs medially toward the petrous apex (Fig. **66**).

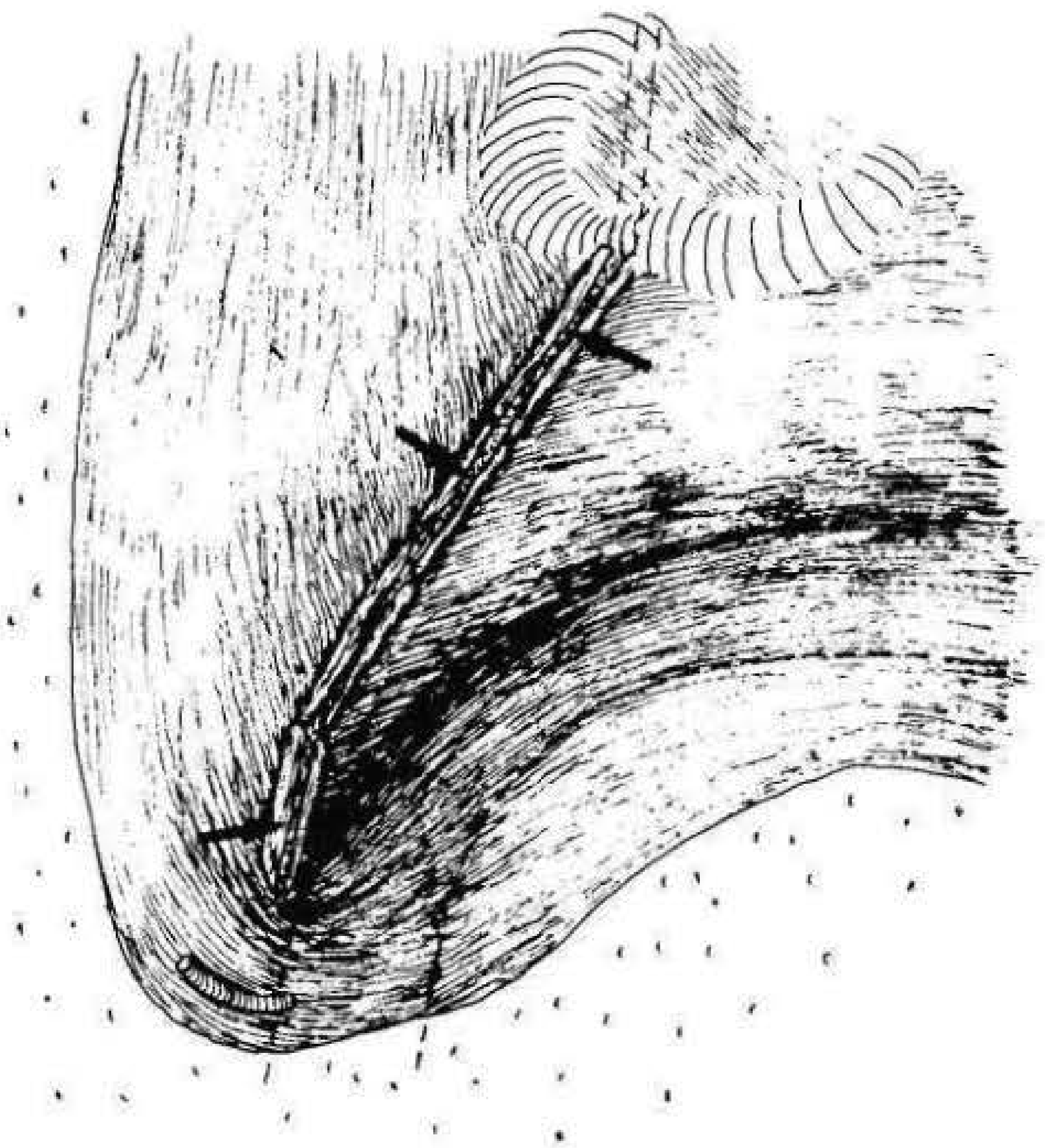


Fig. **65** **The sinodural angle**, with the superior petrosal sinus partly exposed (arrows)

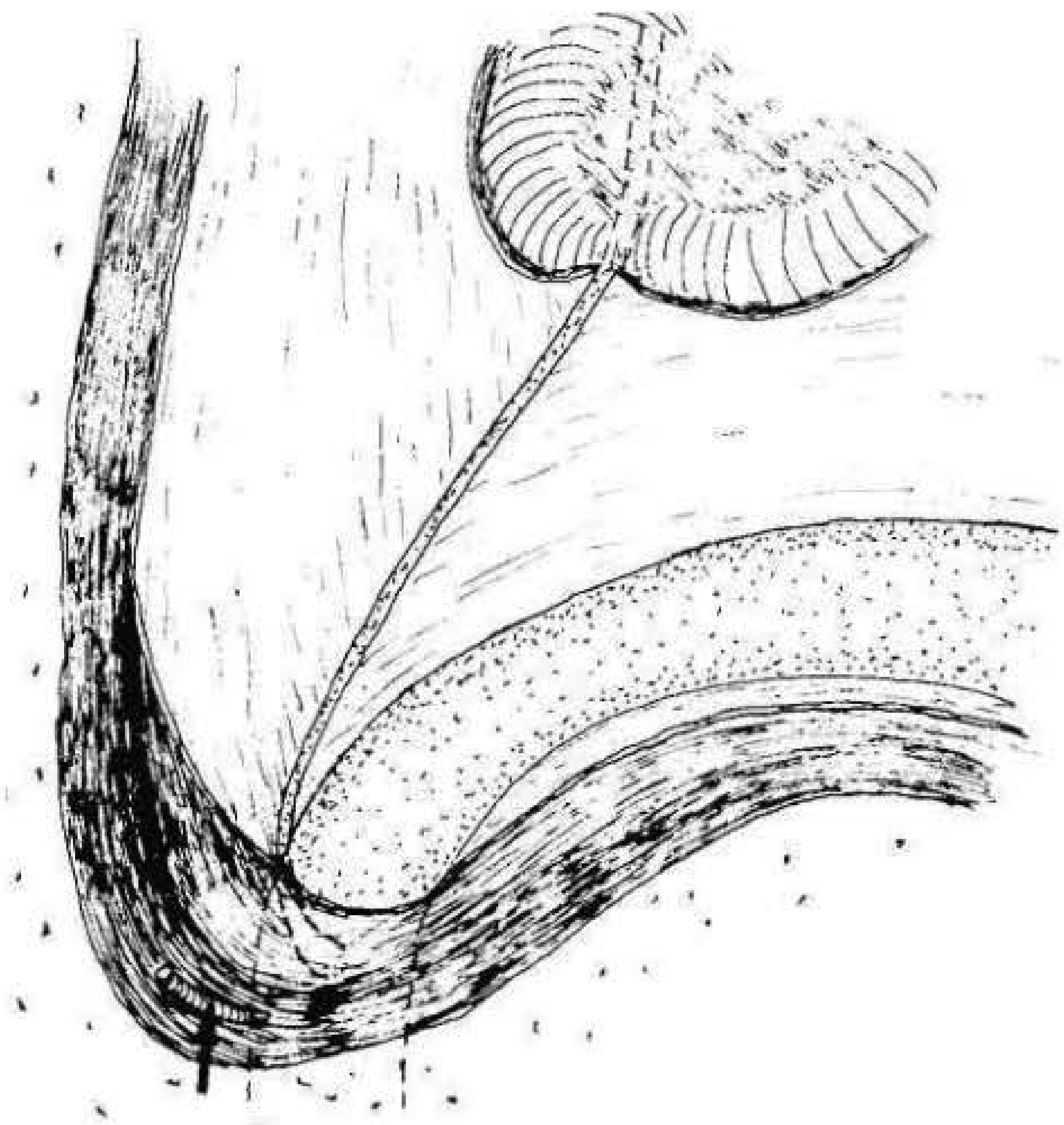


Fig. **66** **The superior petrosal sinus in the sinodural angle**. The dura totally exposed. It runs from the medial (inner) aspect of the sigmoid sinus, deep in the sinodural angle within the duplicature of the dura, in a medial direction beweeen the superior and posterior semicircular canals. Arrow: emissarium mastoideum (Citelli)

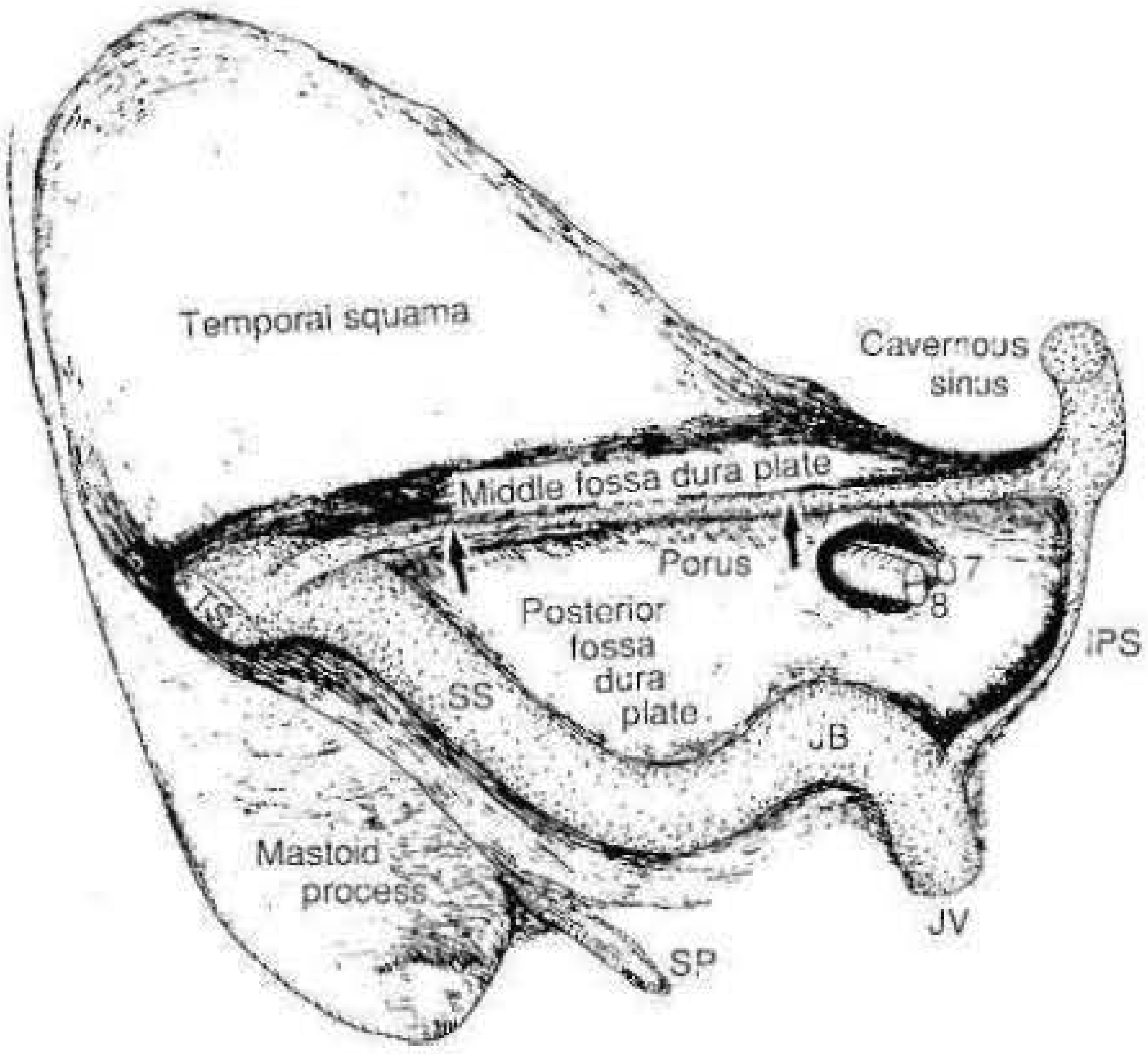


Fig. **67** **The inner surface of the temporal bone**. The superior petrosal sinus lies in its sulcus (arrows) between the middle and the posterior fossa dura plates, connecting the sigmoid sinus (SS) and the cavernous sinus. The inferior petrosal sinus (IPS) connects the cavernous sinus and the jugular bulb (JB). JV: jugular vein, TV: transverse sinus, SP: styloid process

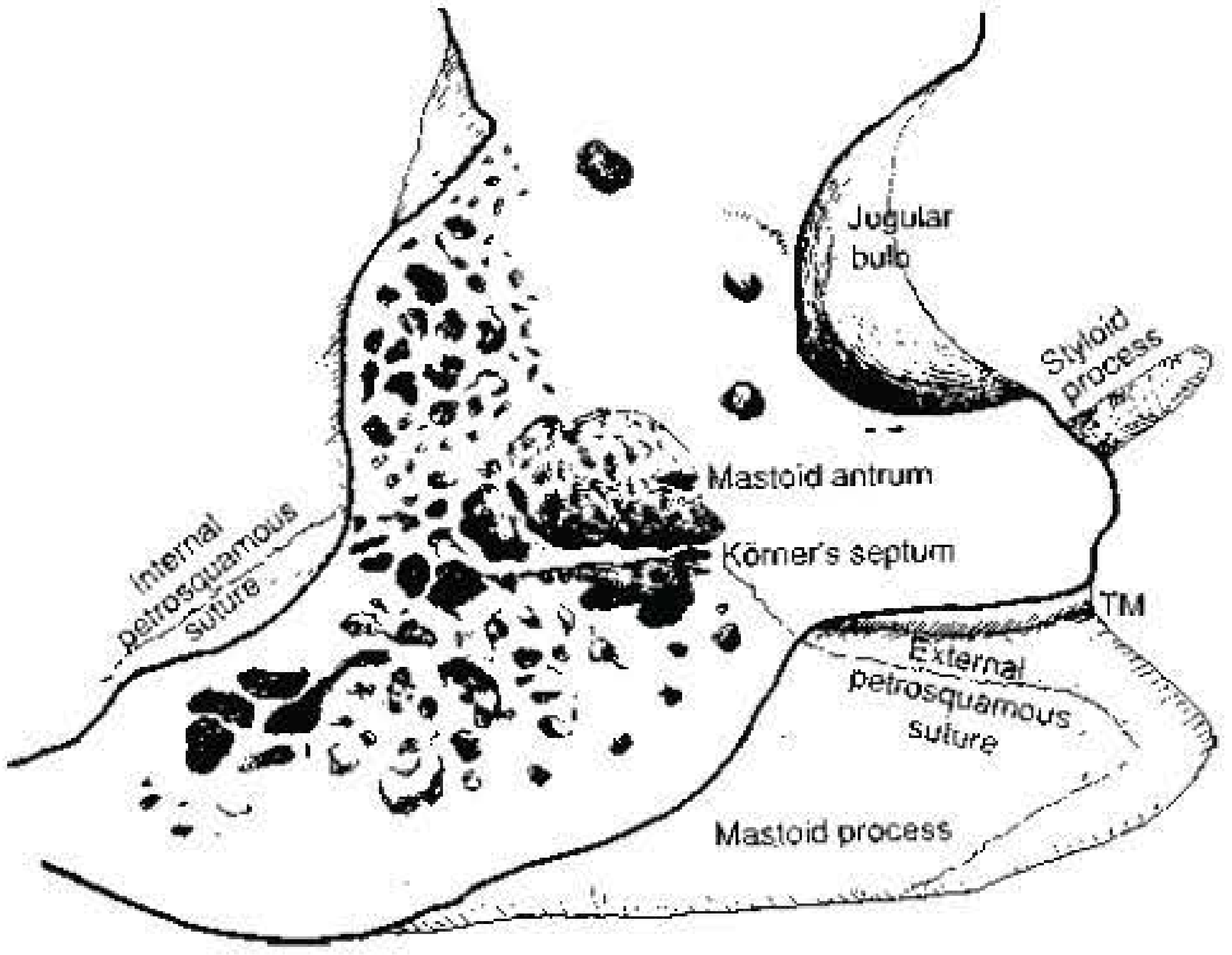


Fig. **68** **Vertical section through the right temporal bone**, partly redrawn after Proctor (1989), showing a well-preserved petrosquamousal lamina (Körner's septum, arrow) continuing superiorly into the internal petrosquamous suture and inferiorly into the external petrosquamous suture, dividing the superficial lateral mastoid cells for these structures into squamomastoid cells and petromastoid cells lying medially to the sutures

Körner's Septum

After exenteration of the superficial mastoid air cells (Fig. **62**), a bony plate can be seen at the bottom of the kidney-shaped cavity. This plate is Körner's septum, or the petrosquamous lamina. In a well-pneumatized mastoid process, the plate of Körner's septum is hardly recognizable (Körner 1899). It is indicated by somewhat smaller cells in the upper part of the cavity (Fig. **63**), but in the lower part, large cells can be present at the level of Körner's septum. Körner's septum represents the site of embryological fusion of the squamous and petrous portions of the temporal bone. Between the two components there is a sutural line that is normally obliterated. Occasionally, however, a plate of bone persists between the two parts, called Körner's septum (Figs. **68**, **69**). Körner's septum may give a false impression of having reached the antrum (Ballance 1919, Caparosa 1972, Goycoolea et al. 1989). When this bony septum is present it divides the mastoid process into a superficial-(squamous)-portion and a deep-(petrosal)-portion, both portions open separately into the antrum (Fig. **69**) (Proctor et al. 1981, Proctor 1989). If the squamous portion is poorly pneumatized (Fig. **70**) or sclerotic, there may be great difficulty finding the mastoid antrum, unless the surgeon is aware that Körner's septum—the petrosquamous lamina—is present and must be penetrated to reach the air cells in the deep portion of the temporal bone. Schullmann and Rock (1972) pointed out that Körner's septum should be considered: 1) if there is difficulty in approaching the

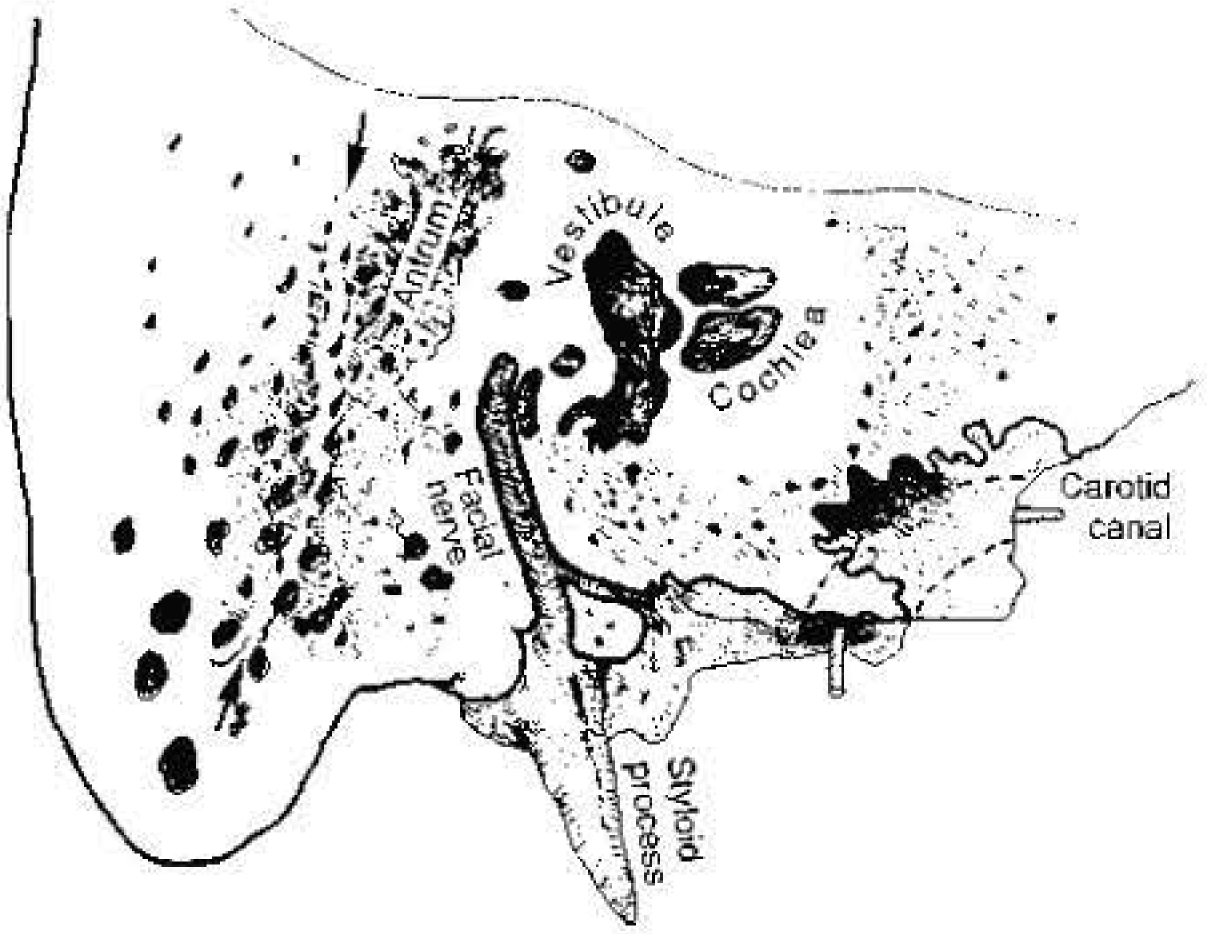


Fig. **69** A similar vertical section through the entire temporal bone, including the petrosal apex, at the level of the vertical portion of the facial nerve, illustrating Körner's septum (arrows), with the mastoid antrum and petromastoid cells medial to it and the squamomastoid cells lateral to it (partly redrawn after Proctor 1989)

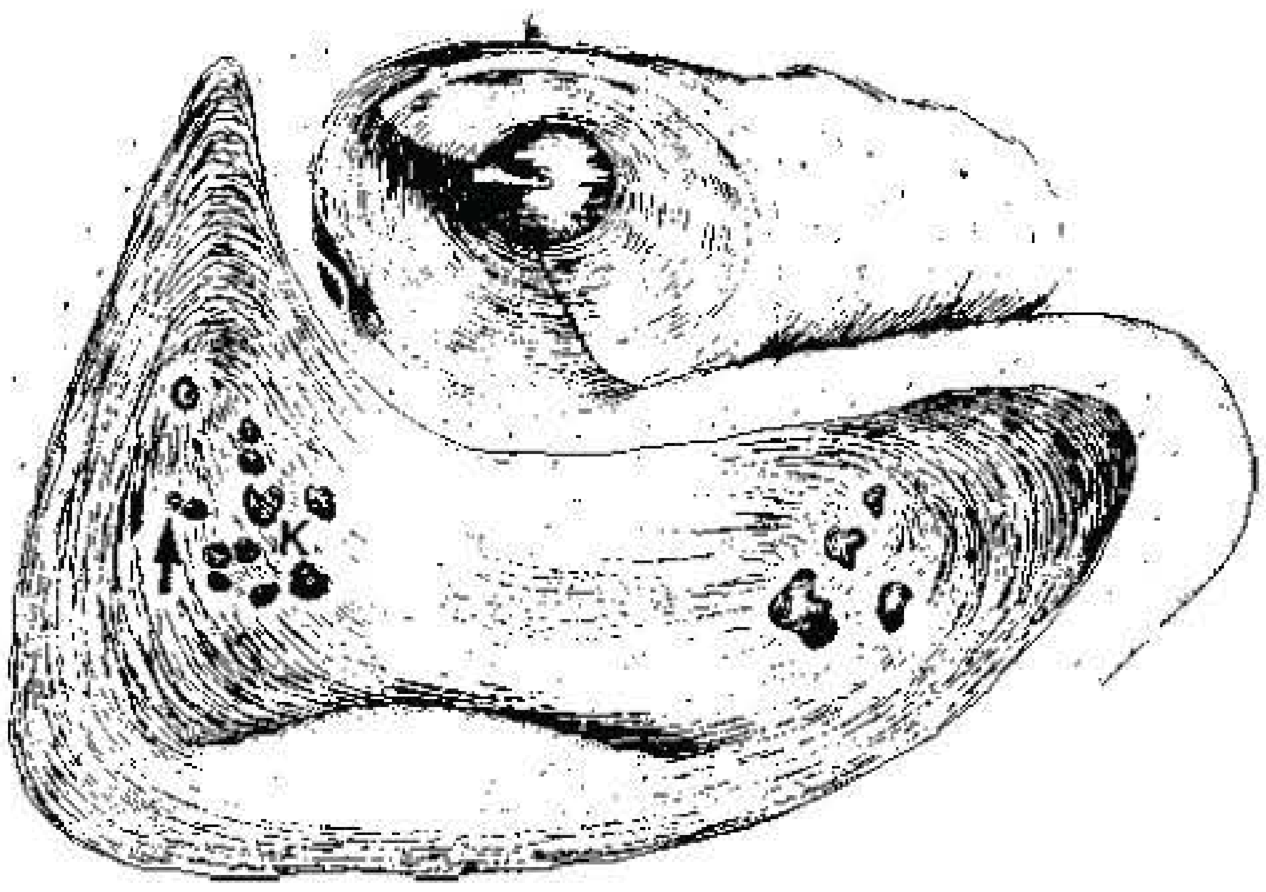


Fig. **70** **Thick Körner's septum (K)** in a poorly pneumatized mastoid process and only few small cells, which should be followed along the middle fossa dura plate toward the antrum (arrow) antrum; 2) if the antrum is small and constricted; and 3) if it is felt that the antrum has an anomalous position.

Whenever a persistent and dense Körner's septum is found, it should be removed to eliminate a dual pneumatic system (Goodhill 1978). Failure to recognize the presence of Körner's septum may lead the surgeon to seek the antrum at a more superficial level. During this procedure, the surgeon may wrongly search for the antrum anteroinferiorly, and may expose and damage the facial nerve. In such cases, drilling along the middle fossa dura plate is therefore extremely important until the antrum and lateral semicircular canal are located.

Mastoid Antrum

Passing the petrosquamous lamina or Körner's septum in an anterosuperior direction along the middle fossa dura plate, the antrum is reached (Figs. **68, 69**). The antrum varies considerably in size; in a small, sclerotic mastoid with little or no pneumatization, the antrum is quite small. In ears with extensive peneumatization, it can be voluminous. In ears with no petrosquamous lamina, there is no border between the large mastoid cells and the antrum. In such cases, the antrum is huge. Anterosuperiorly, the antrum continues along the tegmen to a narrow passage, the *aditus ad antrum* to the epitympanum.

The superior wall of the antrum is the *tegmen antri* (Fig. **61**). The medial wall of the antrum cavity is the labyrinth. Anteriorly, the lateral semicircular canal is immediately recognizable, and lateral to the canal, the incus body and short process of the incus are seen. The posterior and superior semicircular canals are not visualized; they are covered with small air cells or bony spicules (Fig. **71**). The bone surrounding the antrum may be sclerotic, pneumatized with small air cells, or spongiotic in children.

The Labyrinth

When the antrum is entered, the prominence of the lateral semicircular canal should be visible, and this is the most important landmark in the antrum (Fig. **71**). After further removal of the air cells around the superior and posterior semicircular canals, the canals are also visualized (Fig. **72**). The superior semicircular canal runs perpendicularly to the lateral canal, but is about 2 mm deeper (Fig. **73**). The anterior junction of the superior and lateral semicircular canals is at the anterior ampulla. The anterior crus then runs superiorly toward the tegmen

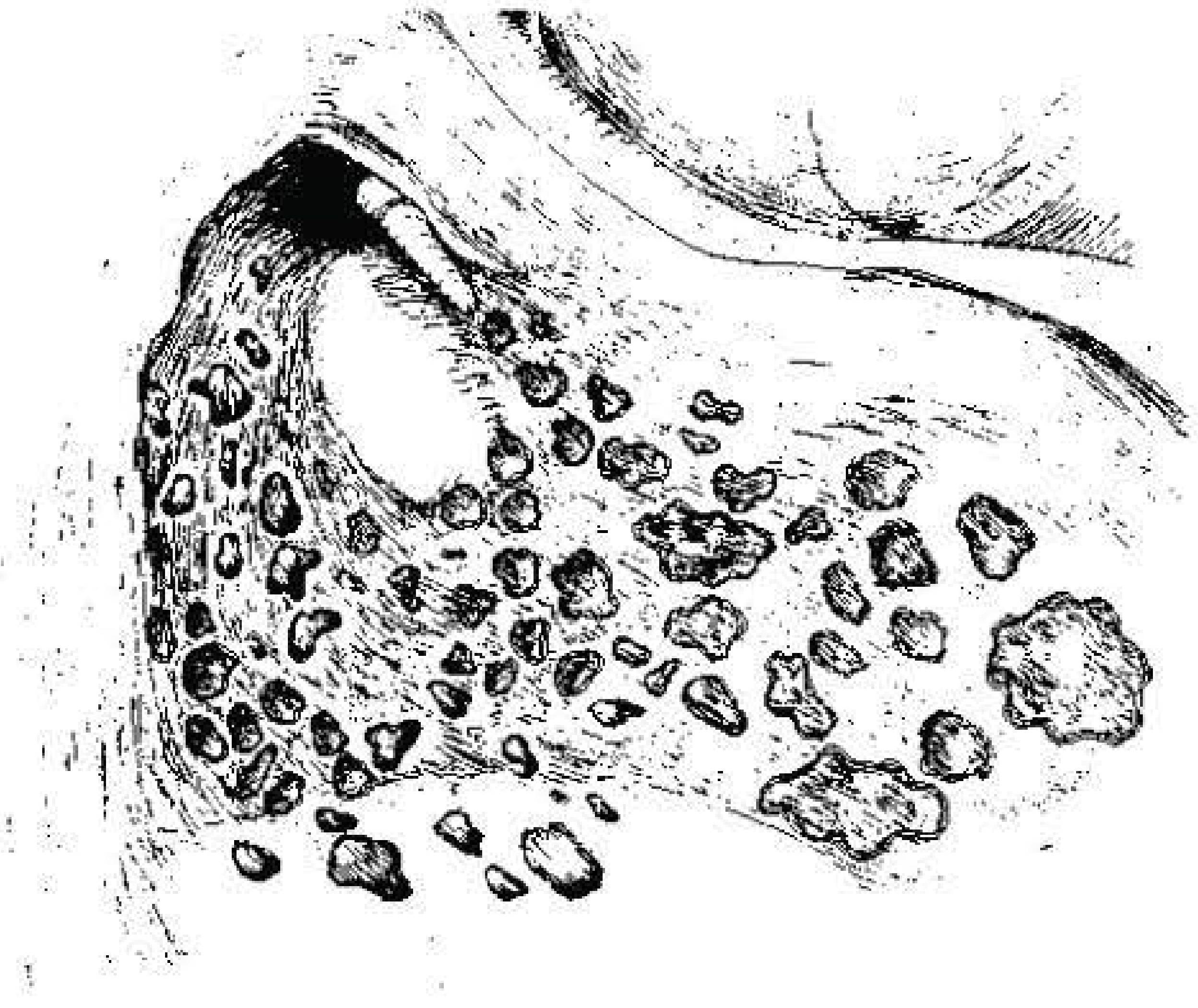


Fig. **71** **Exposure of the mastoid antrum** in mastoidectomy of a well-pneumatized ear. Anteriorly, one can see the incus, malleus, and intact ear canal wall, medially the lateral semicircular canal, and superiorly the tegmen antri. The antrum is surrounded by numerous small periantral air cells, and it communicates anteriorly with the epitympanum through the aditus ad antrum, which is a narrow space between the lateral semicircular canal and the middle fossa dura plate

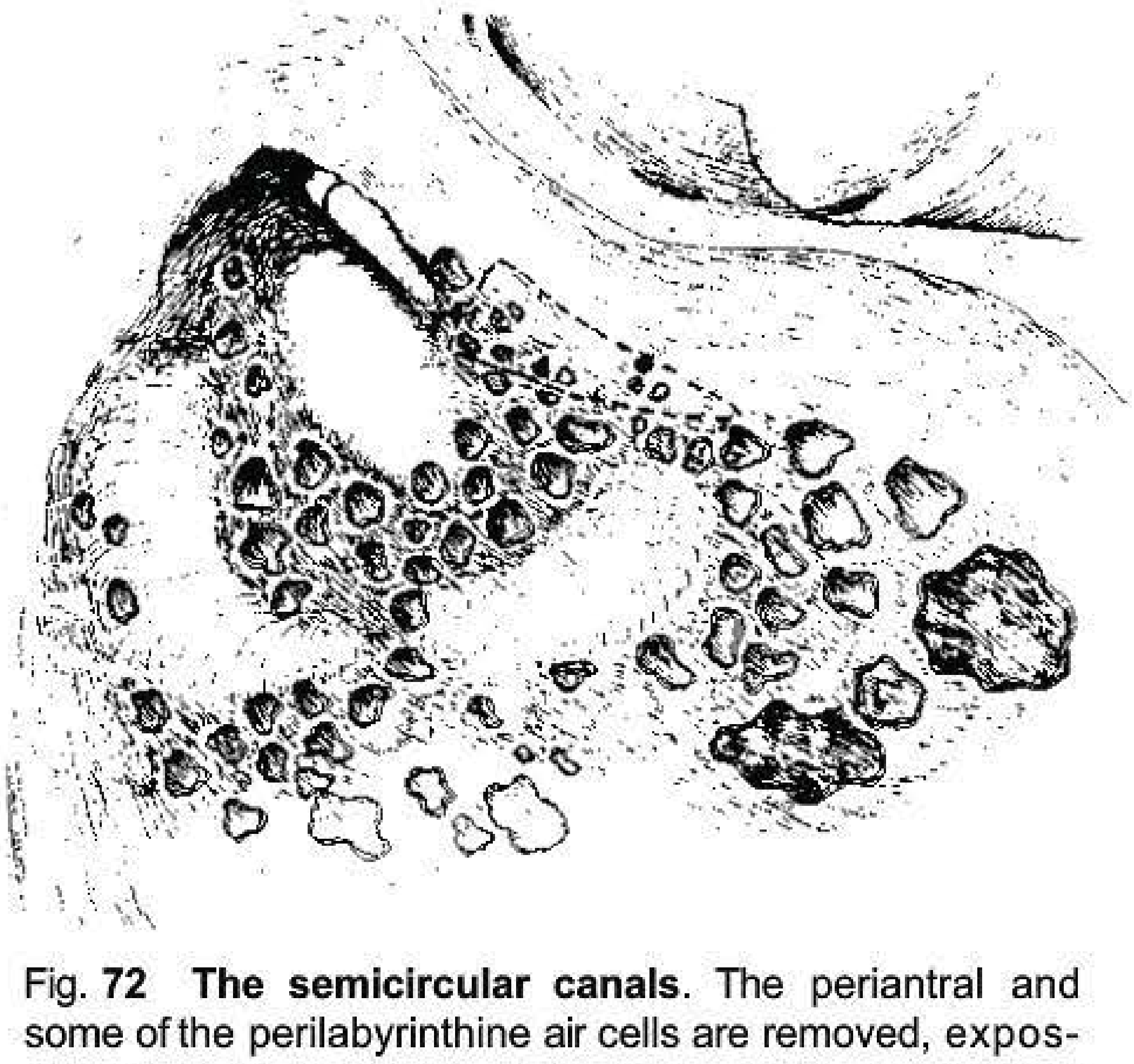


Fig. **72** **The semicircular canals**. The periantral and some of the perilabyrinthine air cells are removed, exposing the most prominent parts of the three semicircular canals: lateral, superior, and posterior. In well-pneumatized ears, these are surrounded by numerous small air cells. The facial recess is indicated by the dashed lines forming a triangle inferior to the incus

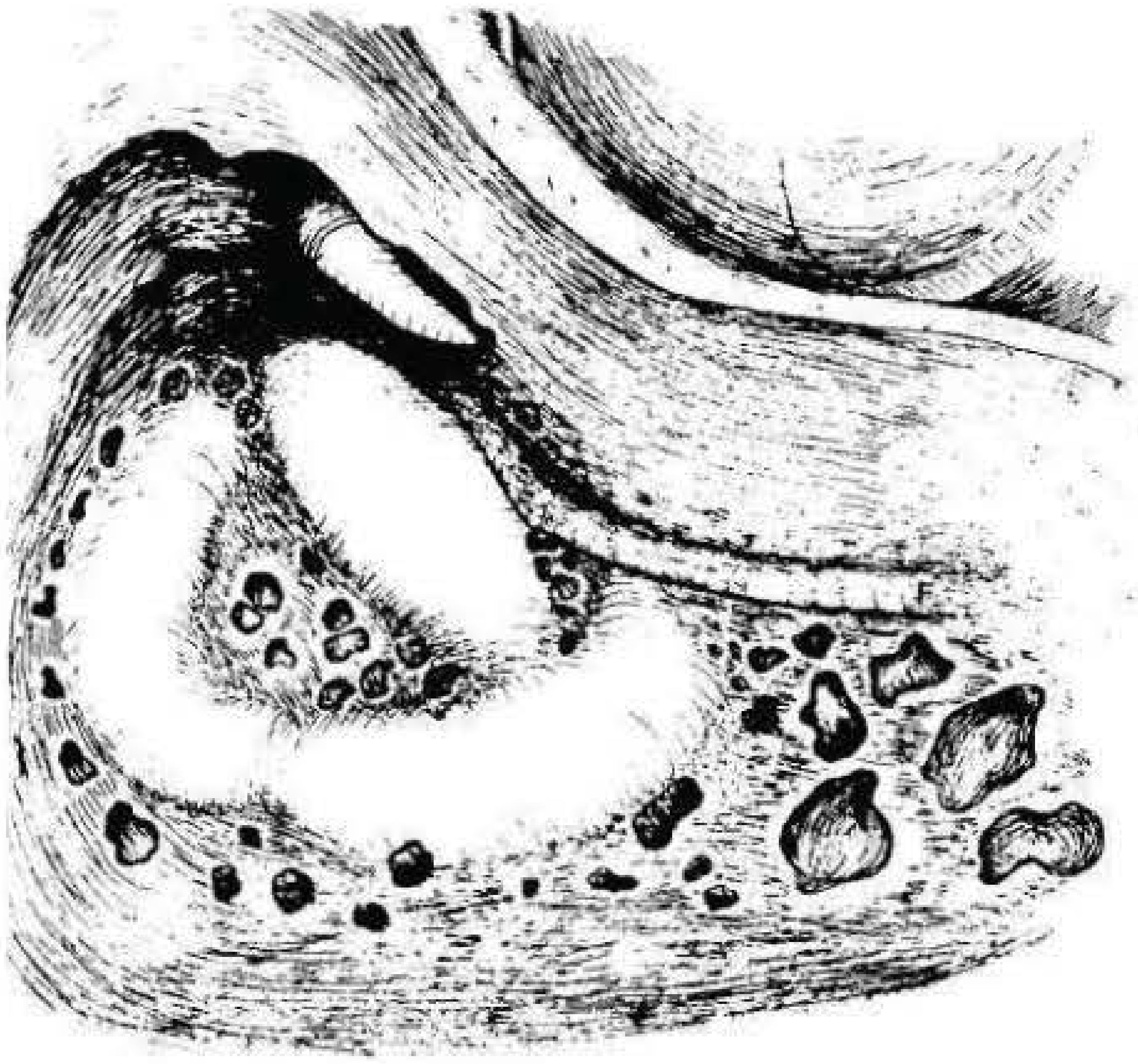


Fig. **73** The supralabyrinthine, infralabyrinthine, and retrolabyrinthine air cells are opened, and the contours of the three semicircular canals are clearly visualized. Anteriorly, the facial nerve (F) is skeletonized

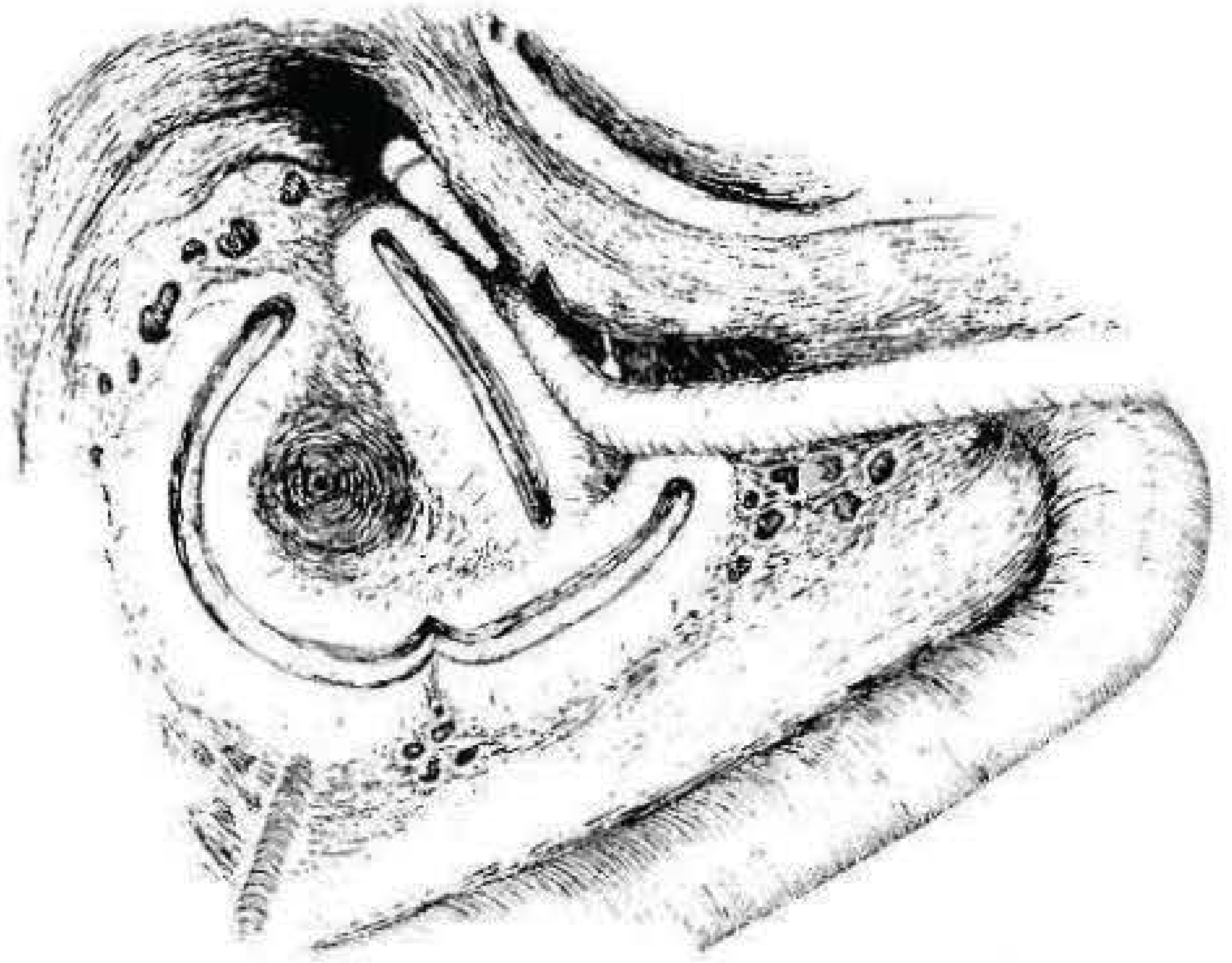


Fig. **74** **The anatomy of the open semicircular canals and their relation to the facial nerve**. The interlabyrinthine air cells have been removed, and the opening for the labyrinthine arteria in the middle of the interlabyrinthine region is visible. Some supralabyrinthine and retrolabyrinthine cells are opened. Infralabyrinthine cells lying inferior to the posterior semicircular canal are visible. Anteriorly, the vertical portion of the facial nerve with its genu is seen. It continues to the horizontal part of the facial nerve situated anteriorly to the lateral semicircular canal. Between the bony ear canal and the vertical portion of the facial nerve, the facial recess is opened. Through the recess, the pyramidal process and the tendon of the stapedial muscle are visible. Posterior to the labyrinth, the posterior fossa dura plate with the skeletonized sigmoid sinus is seen; it runs in an anterior direction under the facial nerve

tympani, and curves posteriorly to join with the posterior semicurcular canal at the common crus (Fig. **74**). The posterior semicircular canal also runs perpendicularly to the lateral semicircular canal. The posterior half of the posterior canal is located posterior to a line bisecting the lateral semicircular canal (Fig. **75**) (Donaldson's line; Anson and Donaldson 1992). The anterior half of the posterior canal runs anteriorly to the Donaldson's line and emerge deep to the facial nerve, to enter the vestibule.

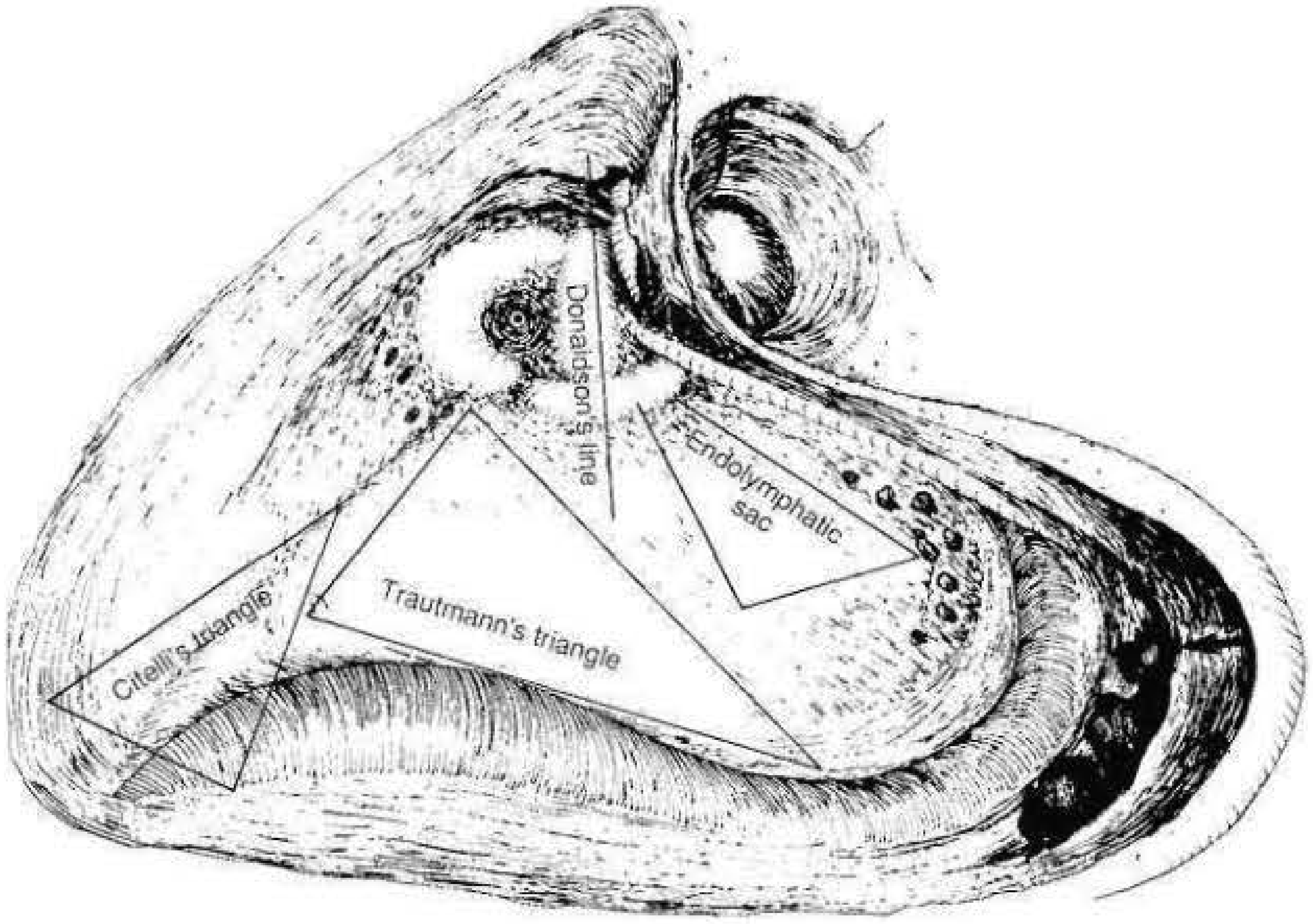


Fig. **75** **Completed extended mastoidectomy with intact canal wall and posterior atticotympanotomy**: superiorly, the entire middle dura fossa plate; posteriorly, the skeletonized sigmoid sinus and the entire posterior fossa dura plate; inferiorly, the sigmoid sinus, the deep mastoid cells, and the digastric crest (arrow). Anteriorly, the skeletonized facial nerve, incus, malleus, and intact ear canal are visible. Medially, the three semicircular canals are seen. Citelli's triangle, the sinodural angle, Trautmann's triangle, the position of the endolymphatic sac, and Donaldson's line, are indicated

The Posterior Fossa Dural Plate

The posterior fossa dura plate is a large bony plate demarcated superiorly by the superior petrosal sinus, laterally and inferiorly by the sigmoid sinus, and medially by the posterior semicircular canal (Fig. **75**). The posterior fossa dura plate forms the posterior wall of the antrum and the posterior wall of the petrosal part of the mastoid process. After locating and skeletonizing the sigmoid sinus, the posterior bony plate is the next structure encountered when drilling medially. It already appears before penetration of Körner's septum and entry to the antrum (Figs. **62, 63, 70**). It is recognized as a solid plate continuing towards the posterior semicircular canal. Most of the posterior fossa dura is included in Trautmann's triangle, an imaginary triangle bounded by the tegmen mastoidei, superior petrosal sinus, sigmoid sinus, and the bony labyrinth. Inferior to Trautmann's triangle and Donaldson's line, the endolymphatic sac is seen, resembling a reflection of the posterior fossa dura (Fig. **75**). The endolymphatic sac continues medially, ending in the endolymphatic duct, which lies within the vestibular aqueduct, a bony canal running posteromedial to the posterior semicircular canal and ending in the vestibule (Fig. **76**).

The tip of the mastoid process in well-pneumatized ears usually contains large air cells. At the same depth as the facial nerve, there is the digastric crest (Fig. **75**). On the external surface of the mastoid process, a corresponding depression occurs. This is the digastric fossa or mastoid incisura, relating to the attachment of the digastric muscle. Inferolateral to the sigmoid sinus and medial to the digastric ridge and the facial nerve, large air cells can be found (Fig. **75**).

Facial Recess

The facial recess lies immediately lateral to the facial nerve at the external genu of the nerve (Fig. **75**). It is usually a collection of small air cells (Fig. **72**), continuing from the antrum towards the facial sinus, but there is no communication between these cells and the tympanic cavity. The facial recess is a surgical term. It is a triangle formed by the facial nerve medially, the chorda tympani laterally, and a bony buttress at the incudal fossa superiorly (Figs. **77, 78**). Access to the tympanic cavity through the facial recess was used by Wullstein (1952, 1968) as "the middle ear inspection hole," and was thoroughly elaborated later by Jansen (1962) in connection with the intact canal wall tympanoplasty technique (Jansen 1972). Jansen called this pro-

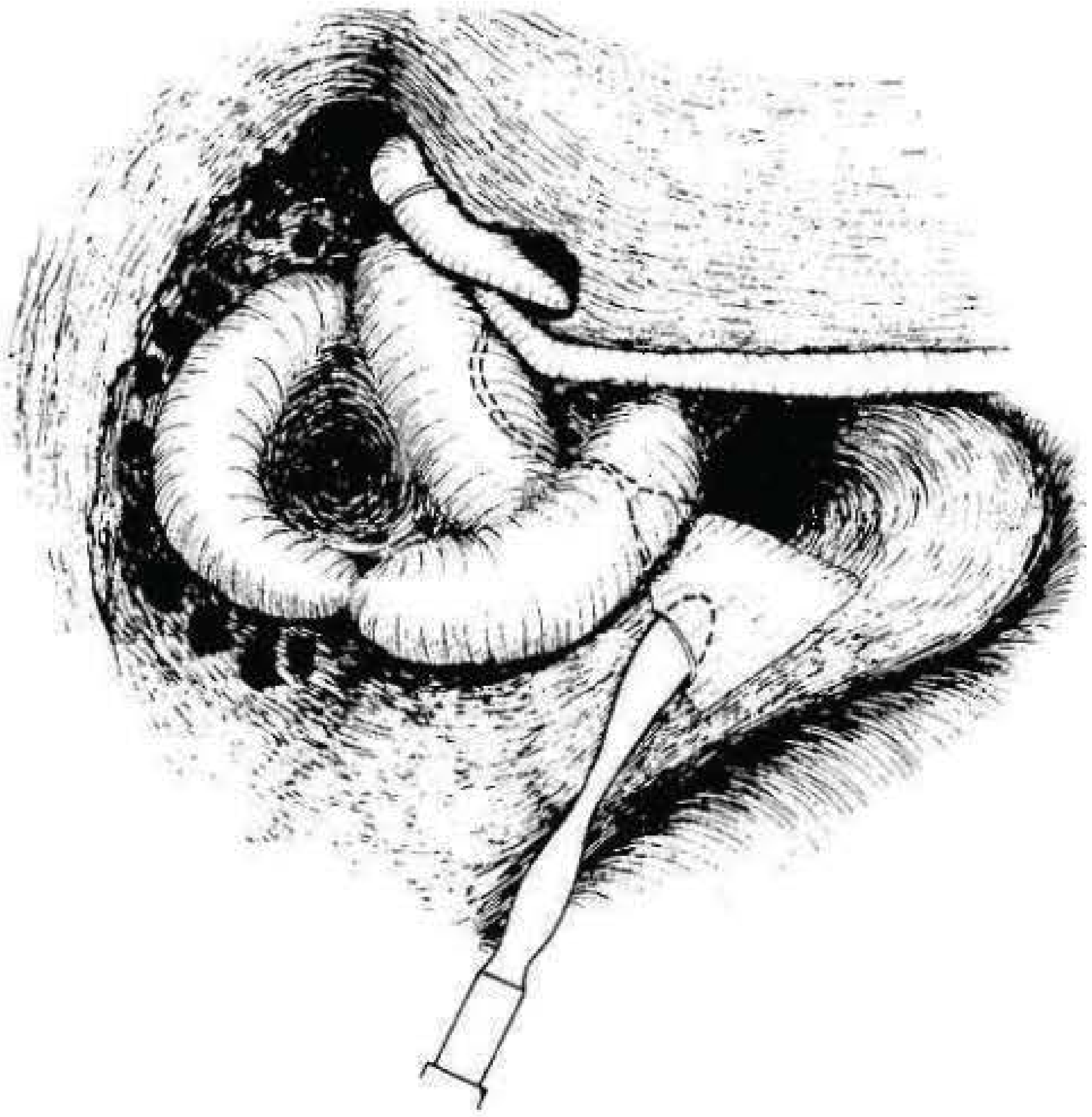


Fig. **76** **Exposure of the endolymphatic sac**, with decompression and opening. The course of the endolymphatic duct, posterior to the posterior semicircular canal toward the vestibule, is indicated by dashed lines

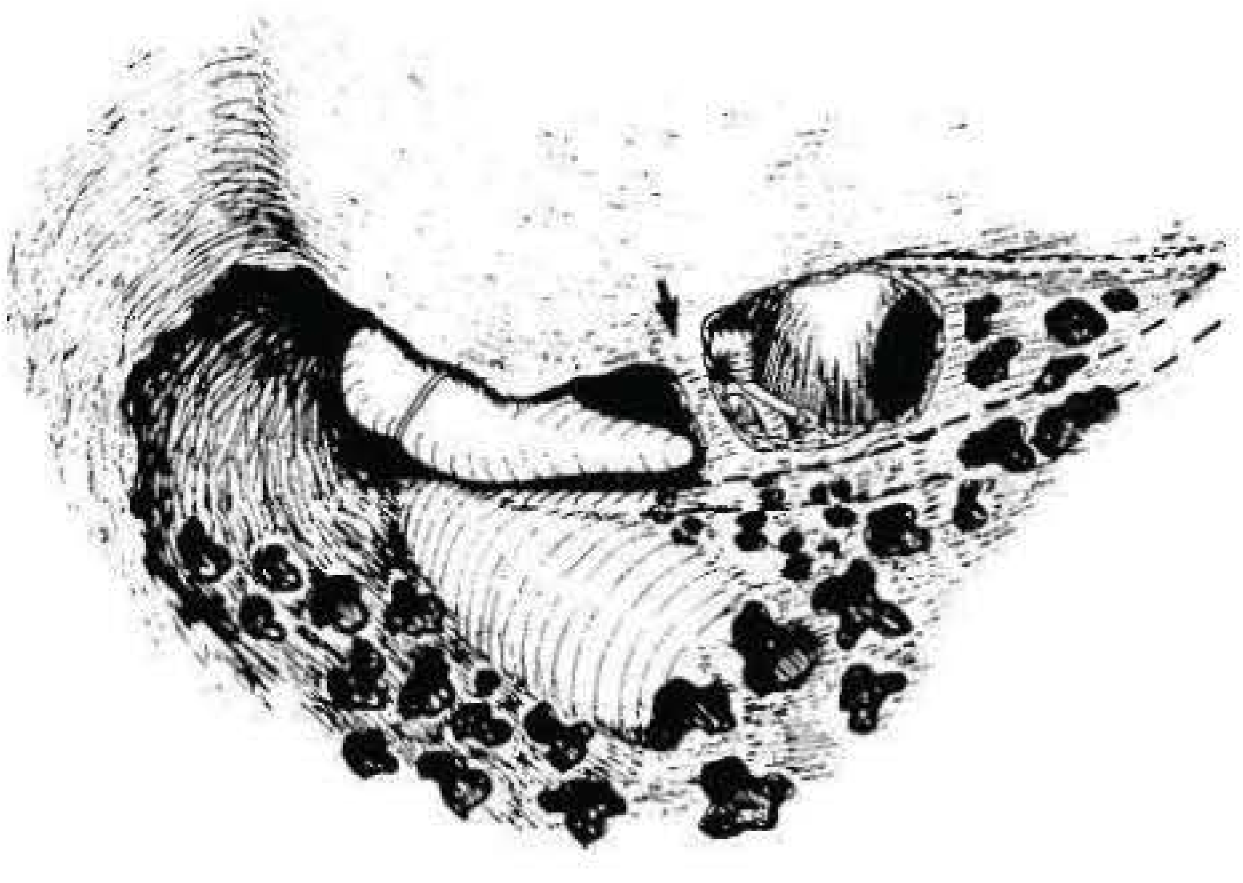


Fig. **77** **The facial recess**. Inferior to the short process of the incus, a widening through the facial recess is drilled out, visualizing the pyramidal process and the incudostapedial joint, as well as the round window niche. The bony bridge between the ear canal and the bone covering the lateral semicircular canal is the posterior buttress (arrow). The course of the chorda tympani and the facial nerve is indicated by dashed lines

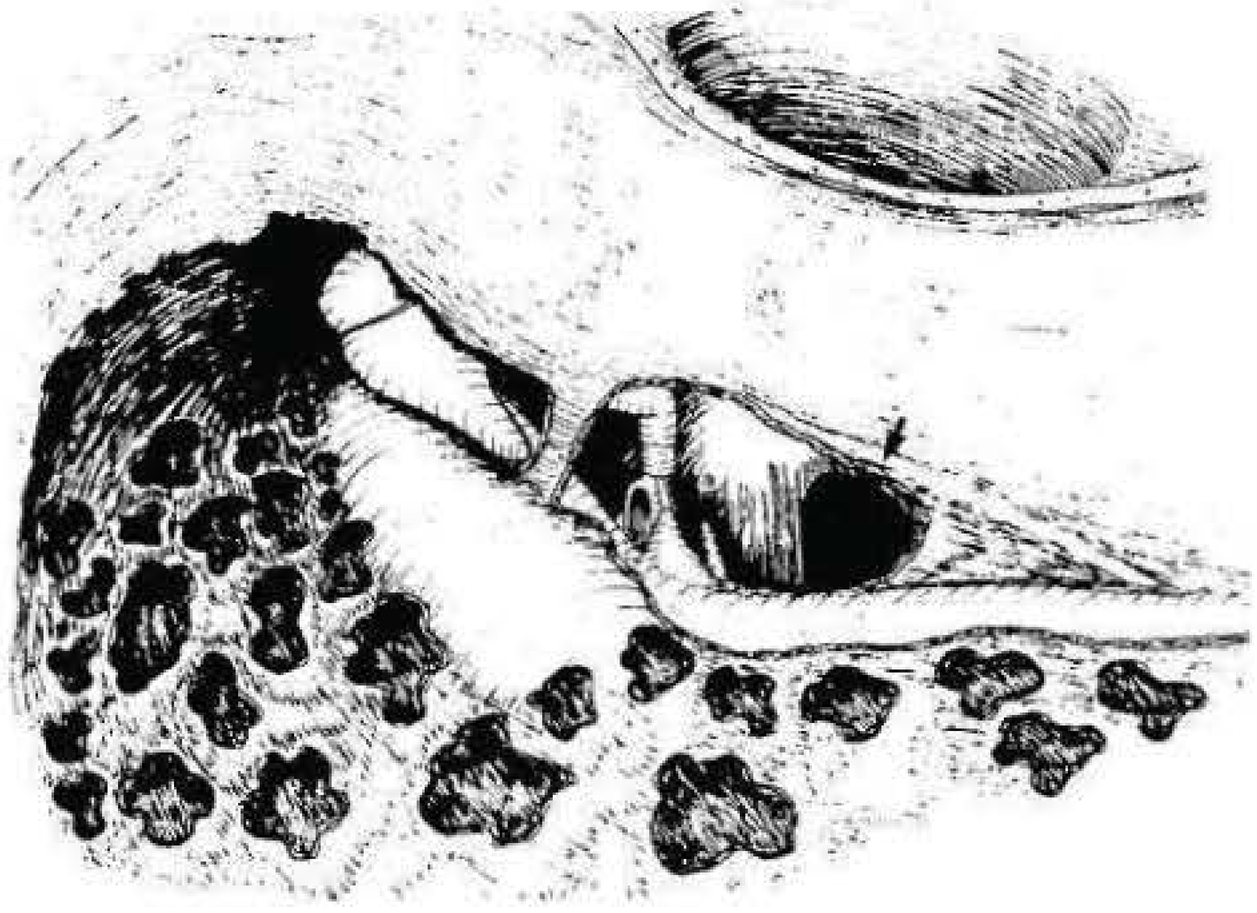


Fig. **78** **Posterior atticotympanotomy**. Below the posterior buttress, the posterior atticotympanotomy is enlarged, exposing and skeletonizing the horizontal and vertical parts of the facial nerve with its genu. Further enlargement of the posterior atticotympanotomy is possible down to the borders between the chorda tympani and the facial nerve. The posterior aspect of the chorda tympani is exposed (arrow)

cedure *posterior tympanotomy,* and the name became very popular. The present author prefers to call Jansen's posterior tympanotomy the *posterior atticotympanotomy,* partly because the procedure consists of drilling and opening via the facial recess from the posterior attic to the tympanic cavity, and partly because the term posterior tympanotomy—like the inferior, anterior, and superior tympanotomies—describes opening of the tympanic cavity from the ear canal by elevation of a tympanomeatal skin flap including the posterior fibrous annulus (Volume 1, pp. 79–86).

The primary aim of a posterior atticotympanotomy is to create a large facial recess during canal wall–up mastoidectomy in order to provide a new route for air flow from the tympanic cavity to the antrum, in addition to the existing routes through the anterior attic and the tympanic isthmus. However, the facial recess is postoperatively often relatively closed off by fibrous tissue or adhesions (Mercke 1986). The other aim is to eradicate disease from the posterior tympanum, especially from the facial sinus and the lateral tympanic sinus, which are located directly lateral to the descending facial nerve canal. Posterior atticotympanotomy also serves many other purposes, especially in facial nerve decompression, cochlear implantation, and several other otoneurosurgical procedures (Figs. **79**, **80**).

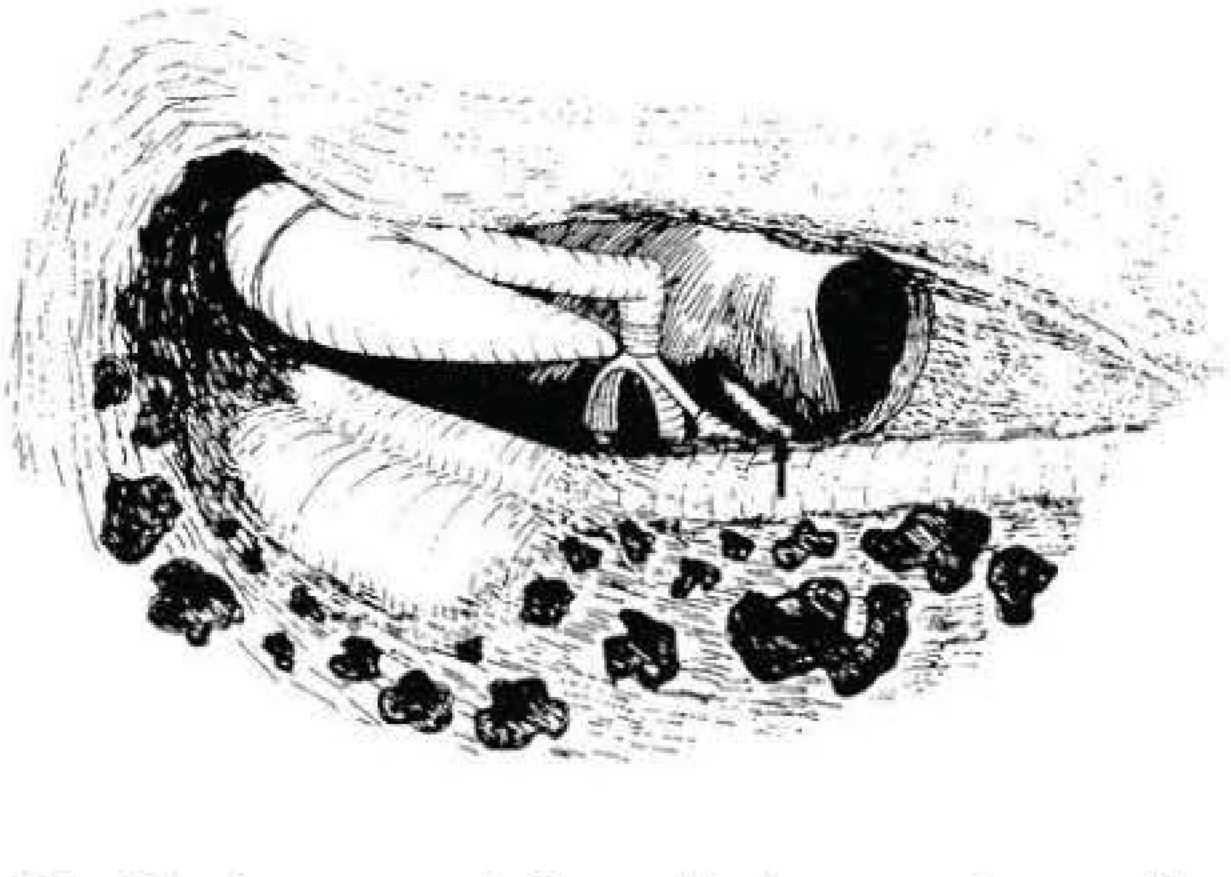


Fig. **79** **Large posterior atticotympanotomy** after removal of the posterior buttress and visualization of the incact ossicular chain and facial nerve, used in decompression of the facial nerve. Inferior to the stapes is the ponticulus (arrow)

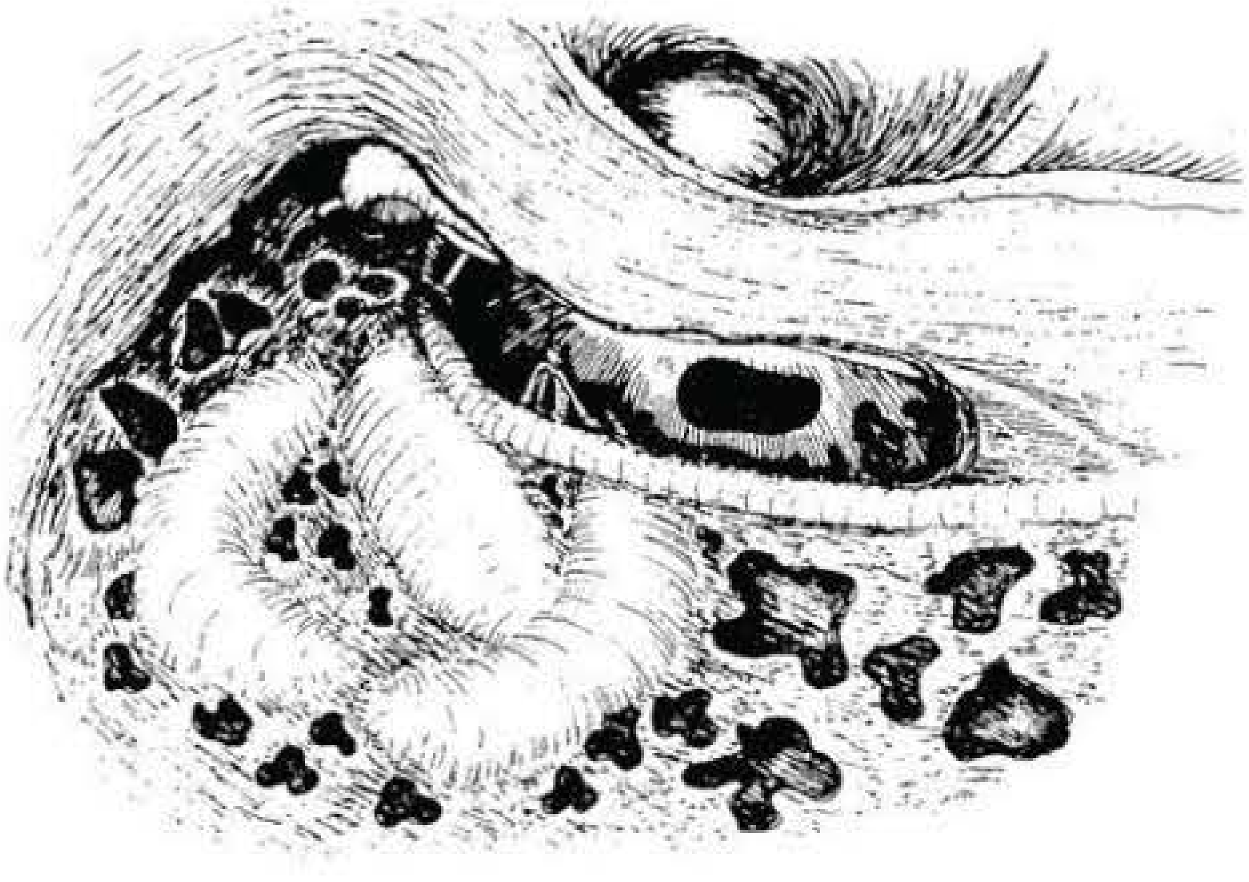


Fig. **80** **Removal of the posterior buttress and the incus**, and further removal of the bone between the facial nerve and the chorda, makes possible a large posterior atticotympanotomy, especially for exposure of the facial nerve in cases with a defective incudostapedial joint

The Attic

The attic or epitympanum is an important structure. It provides communication between the antrum and the rest of the tympanic cavity. Surgically, it is difficult to reach, especially when a low dura is encountered, as is often the case in cholesteatoma surgery. The disease is difficult to eradicate from the attic, and in all series a high incidence of residual cholesteatoma after surgery is reported. The high frequency of postoperative attic retraction and recurrent cholesteatoma indicates that ventilation of the attic is difficult to maintain after surgery.

The superior border of the attic is the tegmen tympani, which is a thin bony wall, at times transparent or even dehiscent. There are often bony trabecula present that resemble air cells (Fig. **81**). These "cells" connect with periantral cells posteriorly and perilabyrinthine cells medially, as well as with the cells of the meatal wall laterally.

The attic is divided into medial and lateral parts. The border between the two parts is formed by the head of the malleus and the incus body (Fig. **81**), the *medial attic* being larger. The distance between the prominence of the lateral semicircular canal and the incus body is 1.7 mm, and slightly less at the level of the malleus head (Savic and Djeric 1986, 1987). The medial attic communicates with the mesotympanum through an opening—the isthmus tympani—bounded by the lateral semicircular canal and the prominence of the facial nerve medially and the aforementioned ossicles laterally (Fig. **82**). The *isthmus tympani* is a narrow, elongated space, and is divided by the long process of the incus into an anterior isthmus, with the tendon of the tensor tympani as its anterior border (Fig. **83**), and a posterior isthmus, bounded by the posterior wall of cavum tympani, the pyramidal eminence, and the buttress at the fossa incudis. The terms *isthmus tympani posticus* and *isthmus tympani anticus* are also used (Savic and Djeric 1986). Through the tympanic isthmus, and especially through the posterior isthmus, sinus cholesteatoma can spread to the attic. The tympanic isthmus is thus extremely important for attic ventilation (Fig. **84**).

The *lateral attic* is located between the outer attic wall laterally—the scutum—and the malleus head and incus body medially (Fig. **82**). Because of the outward projection of the ossicles, the lateral attic is smaller that the medial attic (Fig. **83**). The outer or lateral wall of the attic—the scutum—runs obliquely medially from the tegmen tympani to the upper edge of the bony annulus, making the lateral attic even smaller. The communication between the lateral attic and the mesotympanum varies consider-

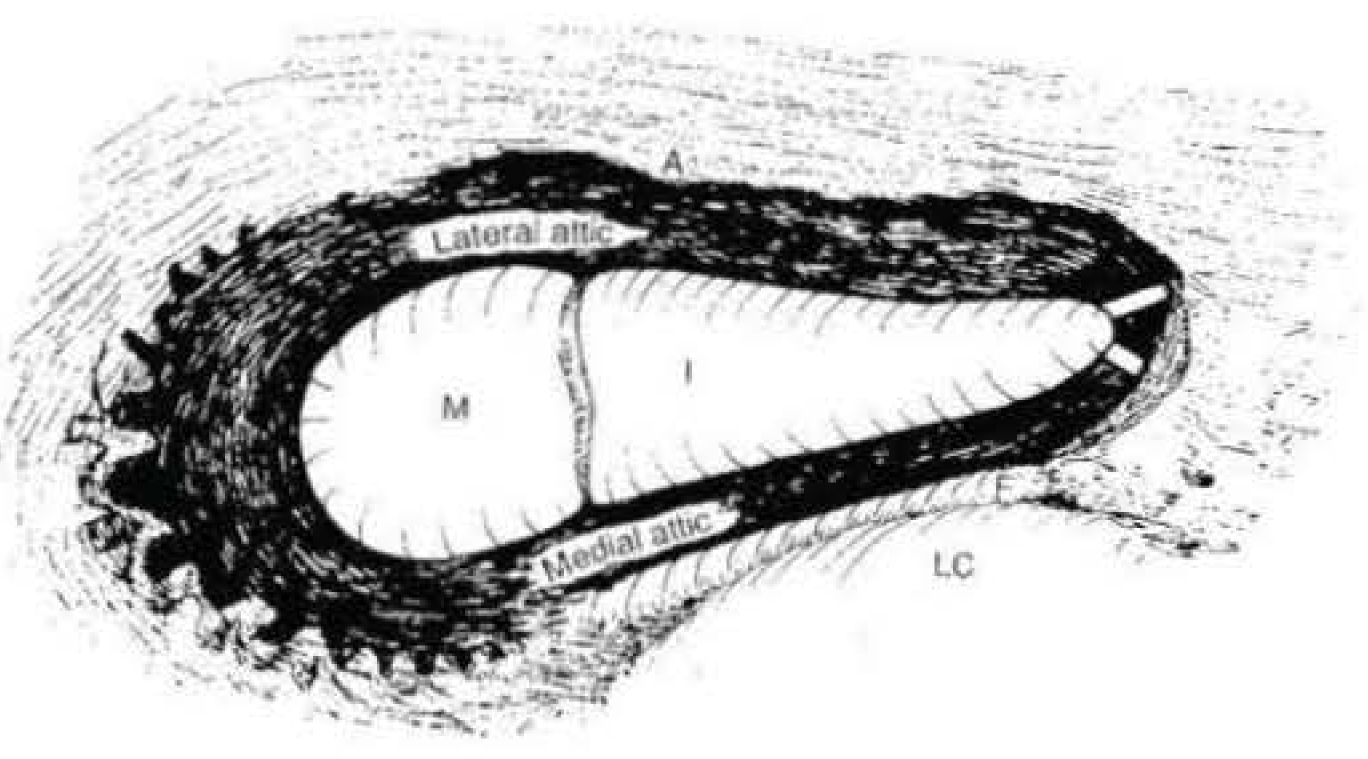


Fig. **81** **The attic or epitympanum, seen from above.** It is divided into the *lateral attic*—the space between the superior bony annulus (A) and the malleus (M) and incus body (I), ant the *medial attic*—the space between the incus and malleus and the facial nerve (F) and lateral simicircular canal (LC). In the superior attic wall, the trabeculae are prominent

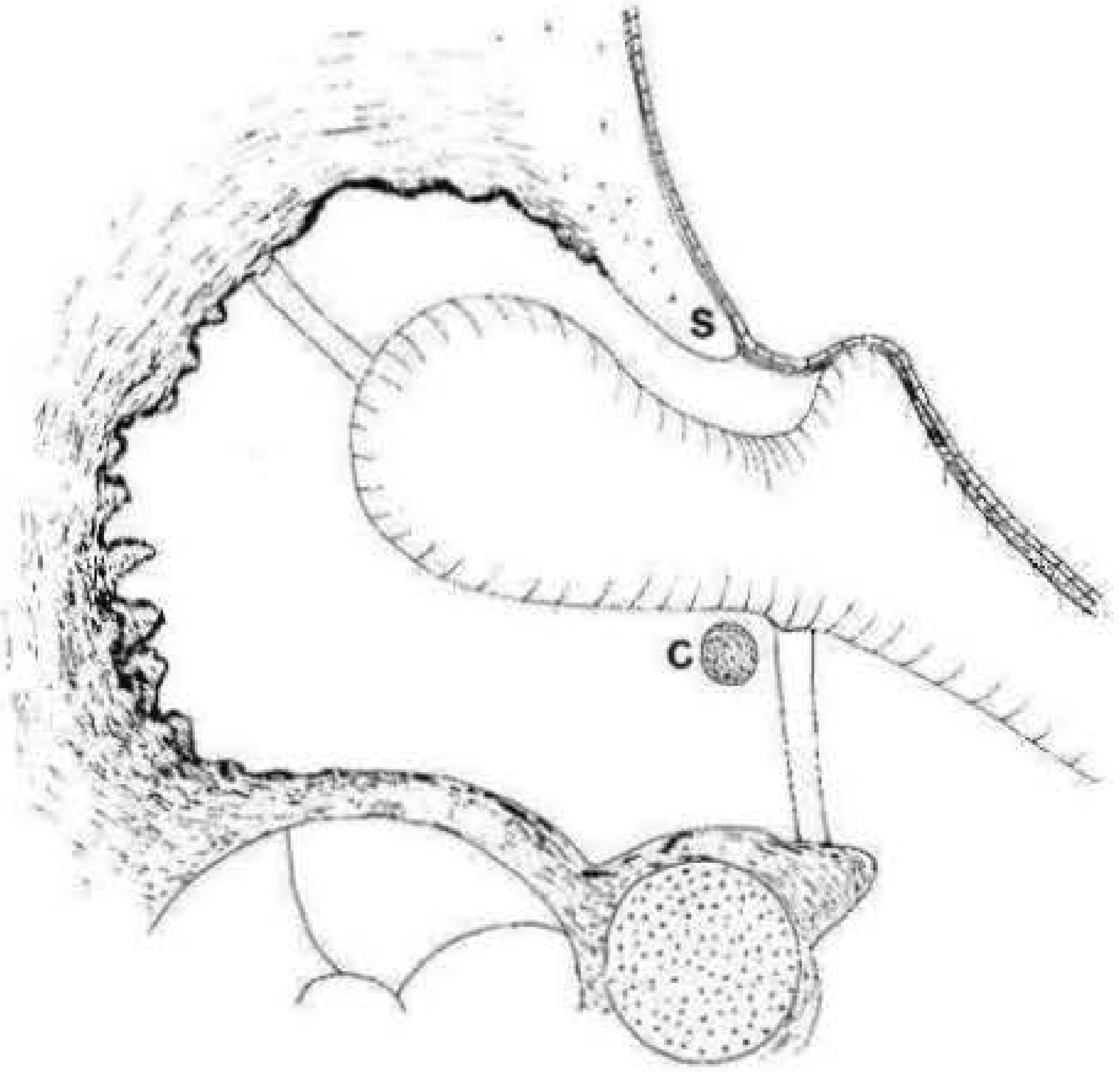


Fig. **82** **The attic seen from behind at the level of the malleus**, showing the superior malleolar ligament superiorly, and the medial malleolar ligament or tendon of the tensor tympani muscle medially, arising from the cochleariform process. The lateral attic is the space between the lateral attic wall with the bony annulus (the scutum) and the malleus head. The medial attic, between the malleus and the lateral semicircular canal, is larger. The posterior part of the medial attic communicates with the tympanic isthmus. C: chorda tympani; S: scutum ably. At the level of the malleus and anterior to the malleus, it is virtually nonexistent. At the level of the incus, the communication varies from a small fissure to a small, oval-shaped cavity. The lower border of this communication is the chorda tympani, and the upper border is the annulus and lateral malleolar ligament (Fig. **84**). The connection is often closed by various small mucosal folds or adhesions.

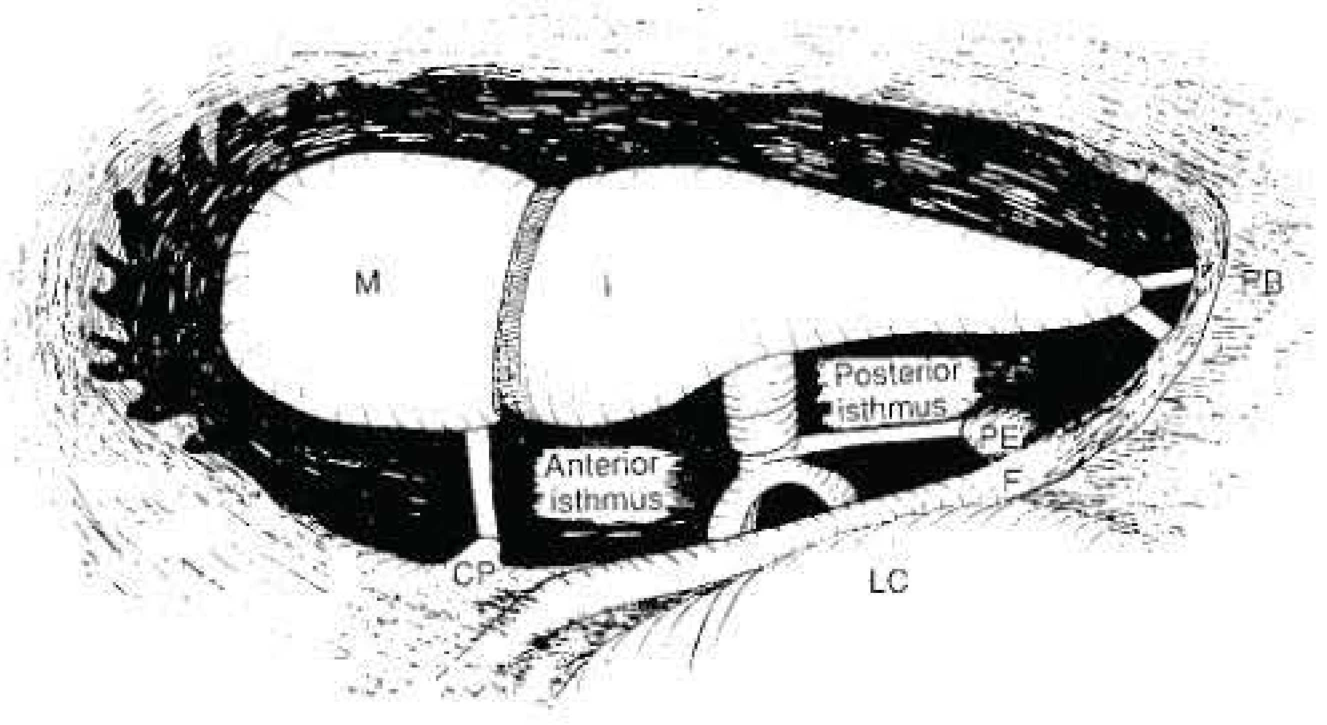


Fig. **83** **The anterior tympanic isthmus** lies between the tendon of the tensor tympani muscle with the cochleariform process (CP), the long process of the incus, and the stapedial arch. The **posterior tympanic isthmus** lies between the long process of the incus, the posterior bony buttress (PB), and the pyramidal eminence (PE). The medial borders of the two isthmi are the facial nerve (F) and the lateral semicircular canal (LC). M: malleus; I: incus

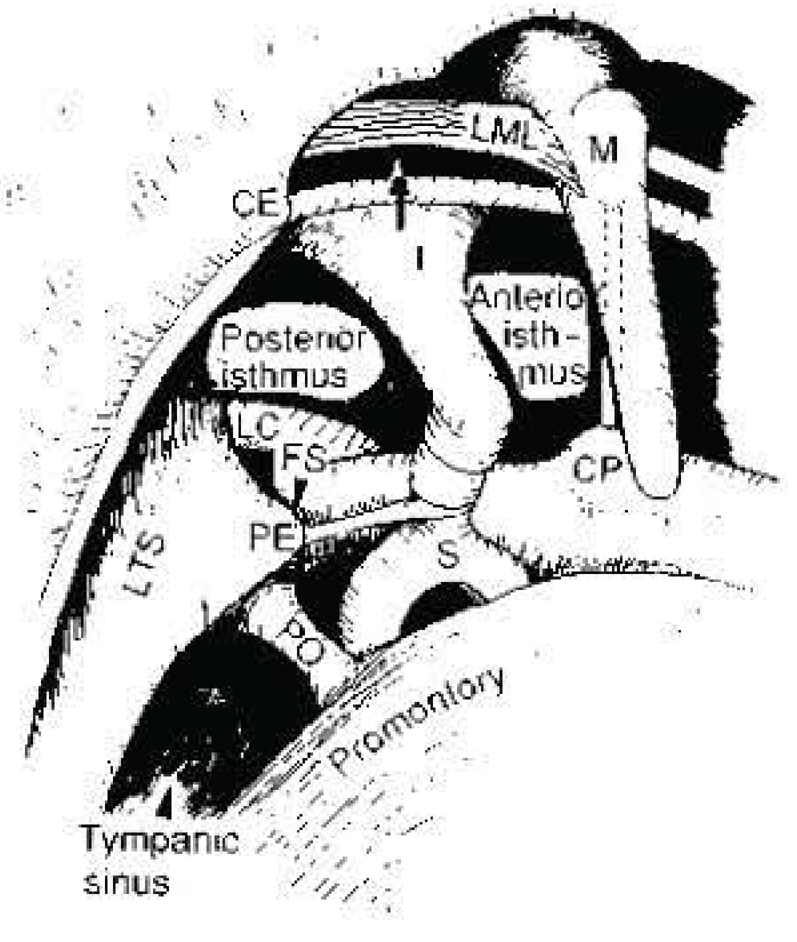


Fig. **84** **The mesotympanum, seen from below**. There is a communication between the mesotympanum and the medial attic through the anterior isthmus, between the incus (I) and malleus (M) and the posterior tympanic isthmus. The mesotympanum communicates with the lateral attic above the chorda tympani (arrow). Above the chorda tympani lie the lateral malleolar ligament (LML) and the bony annulus. LTS: lateral tympanic sinus; LC: lateral semicircular canal; FS: facial sinus; PE: pyramidal eminence, S: stapes, PO: ponticulus, CE: chordal eminence; CP: cochleariform process

The anterior wall of the attic is narrow, and the malleus head is in very close proximity to the bony spicules of the tegmen tympani. The fact that this is a common site for a bony bridge to form between the spicules and the anterior surface of the malleus head is understandable, and it may be caused by simple mechanical irritation in some cases and infection or inflammation in others (Altmann 1965, Tos 1970, Tos 1974 a). But the most common cause of bony fixation is previous surgery, especially previous simple mastoidectomy or atticoantrotomy, indicating that if this region is interfered with by instruments, then the mucosa is disrupted, causing more adhesions at this site. It is therefore best to avoid surgical disturbance to the attic in simple mastoidectomy. If surgery in the attic region cannot be avoided, it is best to remove all bony spicules and to create a large space between the attic wall and the ossicles, in order to avoid postoperative bony fixation.

Part of the explanation for the narrowing of the attic anteriorly is that the tegmen tympani narrows and turns down toward the eustachian tube (Fig. **85**). The anterior border of the attic is usually a bony plate, which also becomes the posterior border of the epitympanic sinus.

The Epitympanic Sinus

The epitympanic sinus is a separate cavity of varying shape and size situated anterior to the attic, the two cavities being separated by a bony crest coming from the tegmen tympani. This crest is called the anterior attic plate (Hoshino and Suzuki 1978; Hoshino 1988; Morimitsu et al. 1989) or cog (Yamasoba et al. 1990). The superior wall of the epitympanic sinus is the tegmen tympani, and in some cases the anterior wall of the tegmen tympani, because of the angulation of the tegmen toward the eustachian tube. In other cases, it is the bony bridge between the sinus and the eustachian tube (Figs. **85, 86**). The medial wall of the sinus is the bone covering the facial nerve at the geniculate ganglion. The lateral wall is formed by the tympanic ring. The inferior border is either the tensor tympani fold or the prominence of the semi canal of the tensor tympani muscle.

The shape of the epitympanic sinus varies. It can be divided into three main types (Yamasoba et al. 1990). *Type A* is a relatively deep sinus anterior to the bony prominence (cog). The sinus is entirely enclosed by bone, except for a narrow opening below the cog. The tensor tympani fold is attached to a relatively thick bony plate anteriorly separating the sinus from the eustachian tube. The tubal recess,

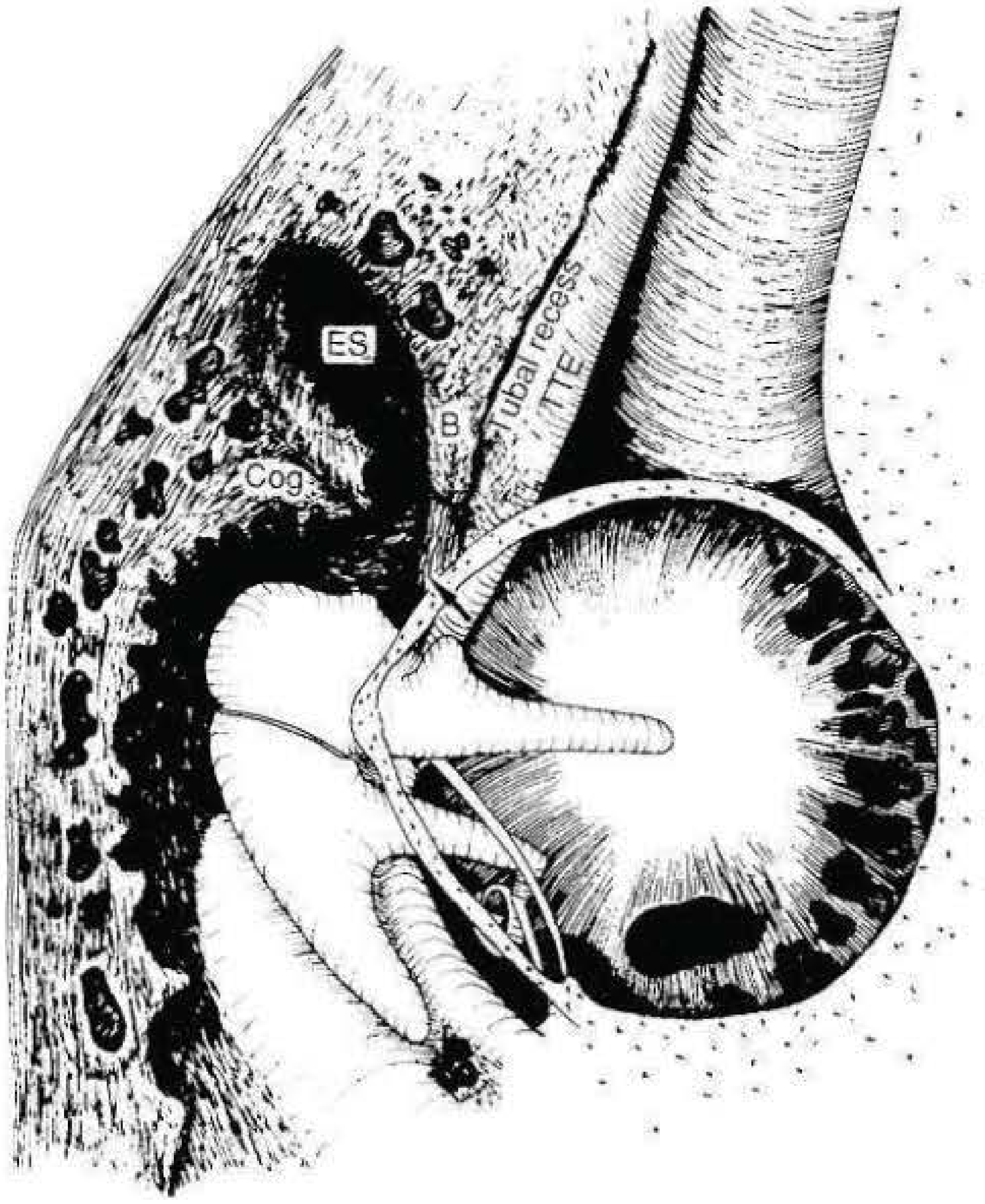


Fig. **85** **The type A epitympanic sinus** (ES). The sinus is deep and totally surrounded by bone, except for a narrow opening below the cog. The pony plate (B) separating the Eustachian tube from the epitympanic sinus is long and prominent, closely approaching the tensor tympani tendon. The tensor tympani fold (arrow) is short, and runs from the bony plate to the tensor tympani tendon. It closes the narrow opening between the cog and the Eustachian tube. The tubal recess (also called supratubal recess) is poorly developed or not present. TTE: tensor tympani muscle eminence

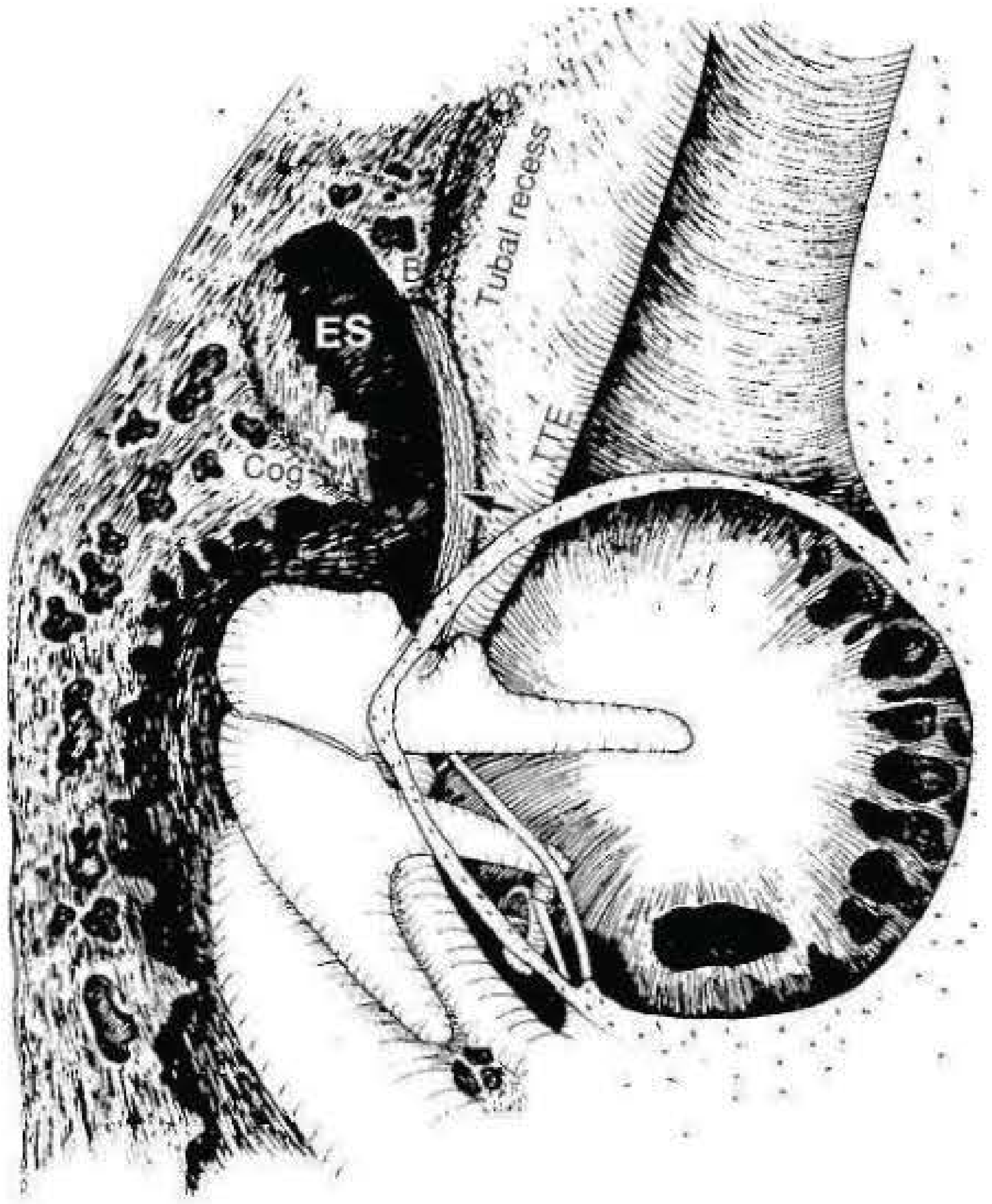


Fig. **86** **The type B epitympanic sinus** (ES). The bony plate (B) between the Eustachian tube and the sinus is poorly developed and short. The tensor tympani fold (arrow) between the tensor tympani tendon and the bony plate is long. The tubal recess is larger than in type A. TTE: tensor tympani muscle eminence

also called the supratubal recess, is poorly developed. This type is found in 38% of investigated cases (Fig. **85**). *Type B* is found in 40% of cases. The bony plate around the tube is poorly developed, and is connected with a long tensor tympani fold. The tubal recess is larger, but the epitympanic sinus is smaller (Fig. **86**). In *type C,* there are no well-defined anterior and inferior boundaries. The sinus slopes down to the eustachian tube and creates a large tubal recess. There is in fact virtually no sinus, but only a large tubal recess. This situation was seen by Yamasoba et al. (1990) in 18% of the cases studied (Fig. **87**).

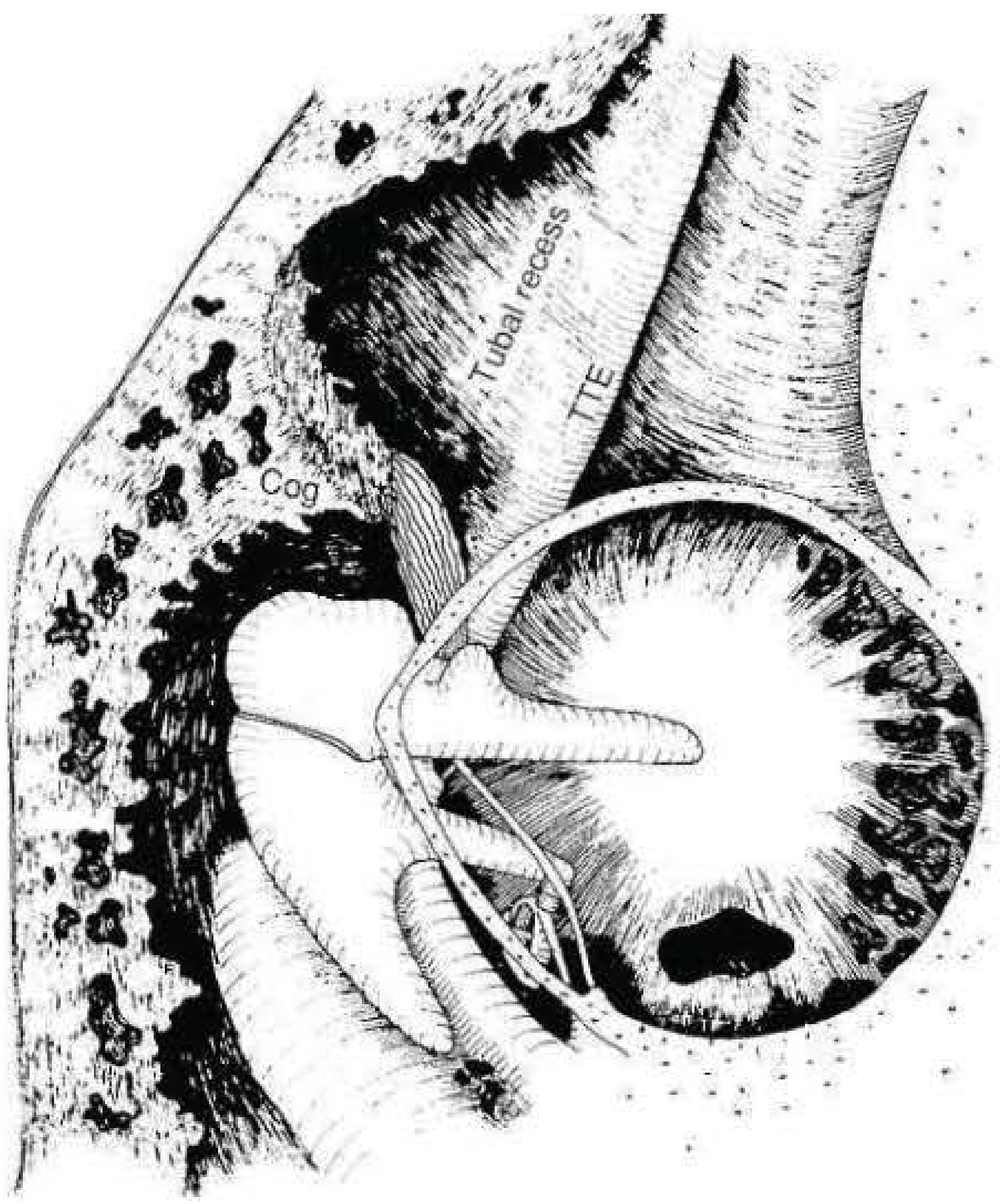


Fig. **87** **The Type C of the epitympanic sinus**, which is not bounded anteriorly towards the Eustachian tube. There is no bony plate between the sinus and the Eustachian tube. The tubal recess is large. TTE: tensor tympani muscle eminence

Since the first description of the sinus by Wigand and Trillsch (1973) as the *sinus epitympanicus,* several other names have been used for it, such as *epitympanic recess* (Schuknecht and Gulya 1986), *anterior epitympanic cell* (Gacek 1980), *anterior epitympanic space* (Hoshino 1988), *supratubal recess* (Horn et al. 1986), and *supratubal space* (Proctor 1964).

The various shapes of the epitympanic sinus make the many names understandable. For type C, supratubal space or supratubal recess are the most appropriate names, since the "space," being large, is hardly a sinus or recess. For type A, the term sinus is more appropriate, as the tubal recess is nearly nonexistent. The air cells around the epitympanic sinus vary, too; in type C, there are several small cells around the sinus, and in type A there are very few cells, or none at all.

In the surgical management of middle ear disease, the structural variation of the epitympanic sinus must be kept in mind. Adequate ventilation from the eustachian tube to the epitympanum can be provided by removal of the cog and the tensor tympani fold in the type C pattern. In such circumstances, damage to the facial nerve, and especially the geniculate ganglion, is possible. The facial nerve, after emerging at the cochleariform process, runs anterior to the lateral and superior semicircular canals toward the geniculate ganglion. The nerve can form the medial wall of the epitympanic sinus or the tympanic recess, and can be damaged in clearing disease from the attic in a canal wall–down mastoidectomy (Fig. **88**). In both types A and B, the bony plate to which the tensor tympani fold attaches should be removed. Removal should be accomplished without division of the anterior malleolar ligament or chorda tympani. The drilling of the cog should be performed medial to the chorda.

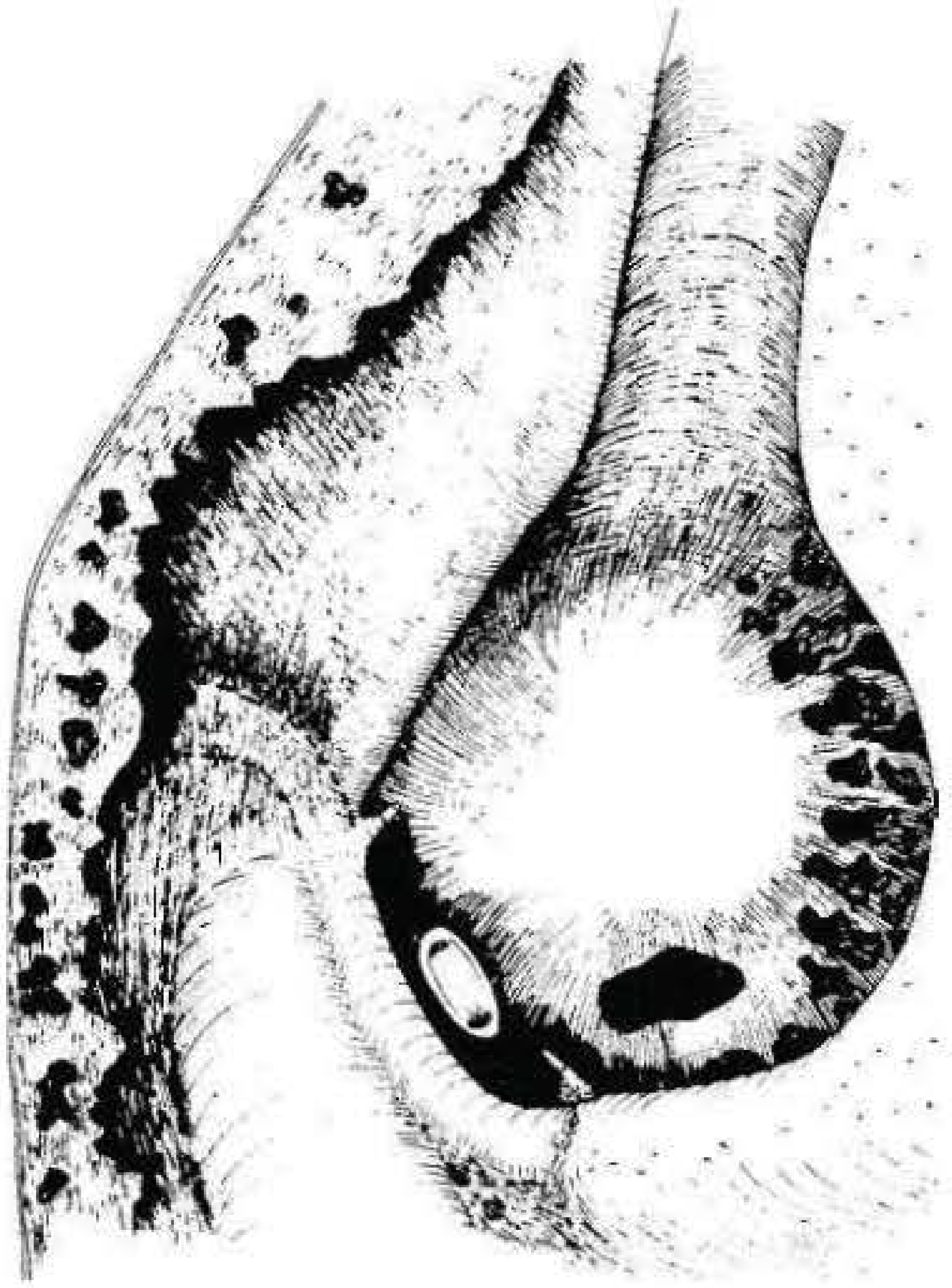


Fig. 88 **Broad connection between the attic and the tubal recess** in a canal wall–down mastoidectomy situation after removal of the cog and bony plate between the epitympanic recess and the tubal recess. The course of the facial nerve from the cochleariform process to the geniculate ganglion is indicated by dashed lines

Pathology, especially cholesteatoma, in the epitympanic sinus may not be recognized, and this can lead to recurrences or even spread of the process towards the tip of the pyramid. Intact canal wall mastoidectomy methods provide poor access to the epitympanic sinus and the anterior attic, and the high incidence of residual cholesteatoma in these regions is therefore understandable.

Posterior Tympanum

The posterior tympanum has the highest -incidence of middle ear pathology, especially retractions and cholesteatomas, which are difficult to remove when they involve the deeper compartments of the posterior tympanum. There are many reports of a high incidence of residual cholesteatoma in all mastoidectomy techniques, with disease located particularly in the posterior tympanum and especially in the sinus tympani (Smyth 1980, Sheehy 1970 a, 1970b, 1990).

The anatomy of the posterior tympanum can be described a) through the ear canal, or b) through the facial recess.

Ear canal. The posterior tympanum can be fairly well visualized through the ear canal using an endaural approach, either with an ear speculum or any of the skin incision approaches (Volume 1, pp. 1.1–33), if the bony annulus is drilled away and the patient's head is tilted backward.

In the posterior tympanum, there are four sinuses, none of which are visible without tilting the patient or drilling off at least part of the bony annulus (Fig. **89**). Two are located suprapyramidally, i. e., superior to the pyramidal eminence—the *facial sinus* and the *posterior tympanic sinus.* Two are infrapyramidal—the *lateral tympanic sinus* and the *sinus tympani.* In relation to the facial nerve in the posterior tympanum, two sinuses are lateral or external to the nerve—the *facial sinus* and the *lateral tympanic sinus,* whereas the posterior tympanic sinus and the sinus tympani are medial to the nerve. The facial sinus is the superolateral sinus, the lateral tympanic sinus is the inferolateral sinus. The posterior tympanic sinus is the superomedial sinus, and the sinus tympani is the inferomedial sinus.

The lateral tympanic sinus. In relation to the bony annulus, this is the most lateral sinus. It lies between the three eminences of the styloid complex (Proctor 1969): medial to the chordal eminence, inferior to the chordal ridge and pyramidal eminence, and superior to the styloid eminence (Fig. **89**). The lateral tympanic sinus is hidden just medial to the bony annulus, but it is most often involved in middle ear diseases especially in the posterior retraction of an atrophic drum (Fig. **84**). Its major axis varies from 1.5 to 2.5 mm, its depth is 2.5 mm (Gersdorff and Maisin 1984). There is no communication between the lateral tympanic sinus and the attic or antrum.

By careful drilling of the posterior bony annulus around the tympanic chorda, the lateral tympanic sinus can usually be approached using the endaural approach. Sometimes the chorda has to be sacrificed when removing the bony annulus to visualize the lateral tympanic sinus.

The *facial sinus* is also a lateral sinus. It is situated at the genu of the facial nerve canal, medial to the bony annulus and chordal eminence, but superior to the chordal ridge and the pyramidal eminence (Figs. **89, 90**). There is no connection between the facial sinus and the air cells of the attic or mastoid process. When approaching from behind through the facial recess, the facial sinus is entered directly. It lies on the facial nerve canal. Sometimes it extends inferiorly to the attic toward the angle between the chorda and the facial nerve canal. Failure to clear the disease from the facial sinus in radical or conservative radical operation is the most common cause of residual cholesteatoma (Proctor 1989).

The posterior tympanic sinus is a medial sinus. It lies medially to the facial nerve and the pyramidal eminence, but superior to the ponticulus—a bridge located between the posterior tympanic wall and the promontory (Fig. **90**). In fact, it is the ponticulus that divides the tympanic sinus into the smaller posterior tympanic sinus and the larger inferior sinus, called the sinus tympani. This division was defined by Proctor (1989).

The *sinus tympani* is the largest sinus. It is a medial and infrapyramidal sinus. It lies deep to the descending part of the facial nerve, inferior to the ponticulus and the pyramidal eminence, and extends down to the styloid eminence (Fig. **89**). At the inferior border of the tympanic sinus, a small

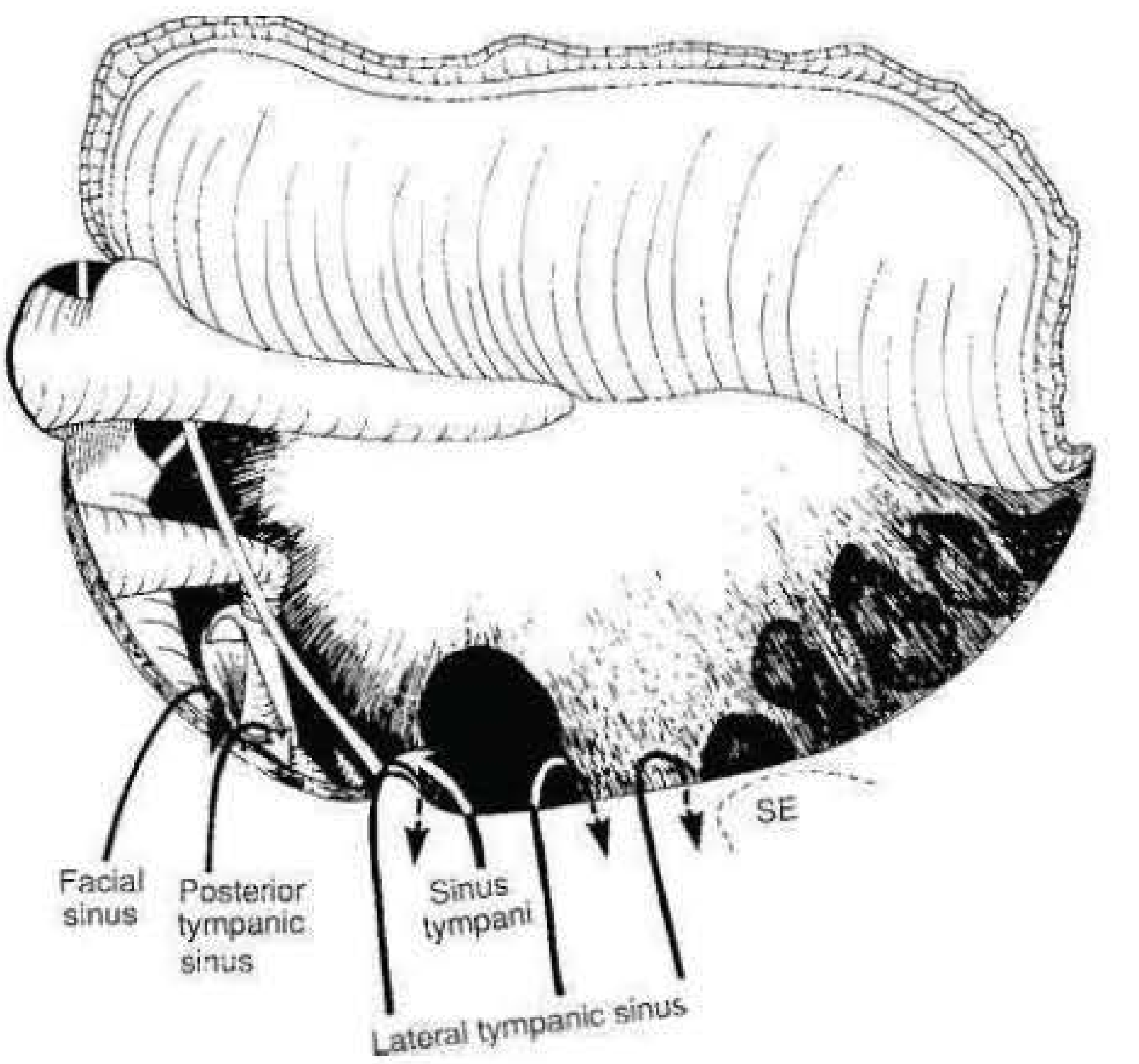


Fig. **89** **Location of the sinuses in the posterior tympanum**. The most superior lateral sinus is the facial sinus. The lateral tympanic sinus lies between the chorda eminence and the styloid eminence (SE). The posterior tympanic sinus and the sinus tympani are located medially

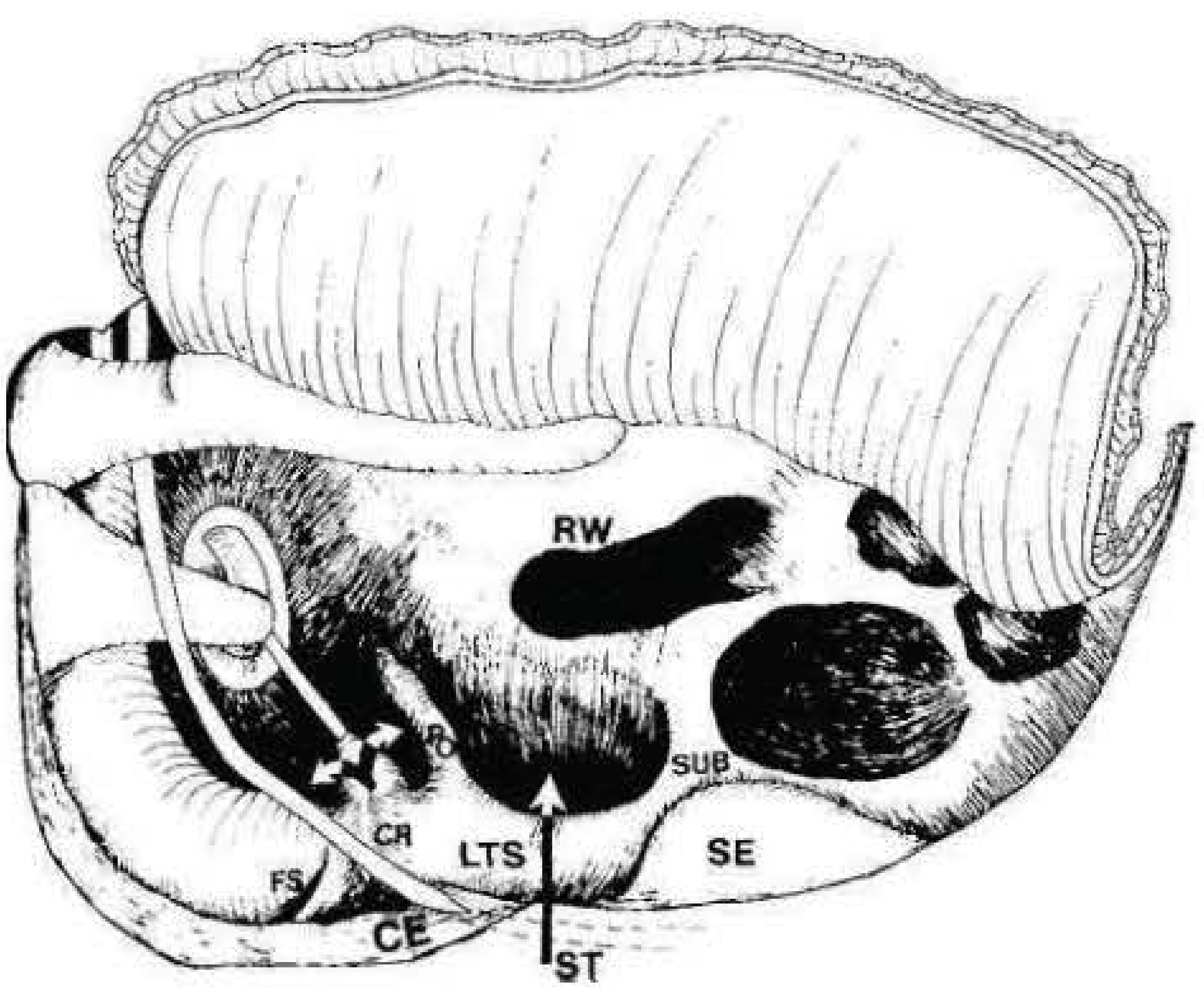


Fig. **90** **The sinuses of the posterior tympanum** after otosclerosis drilling of the posterosuperior bony annulus and maximal tilting of the patient backward. FS: facial sinus; PO: ponticulus; PE: pyramidal eminence. The double arrow indicates the posterior tympanic sinus, partly posterior to the stapes and superior to the pyramidal eminence, partly in the space between the ponticulus and the stapes. The lateral tympanic sinus (LTS) lies between the chordal eminence (CE) and the styloid eminence (SE). The large arrow is indicates the sinus tympani (ST) lying beween the ponticulus (PO) and the subiculus (SUB). RW: round window niche. The chordal ridge (CR) is visible between the chordal eminence and the pyramidal eminence bony bridge is located, the subiculum, which runs from the styloid eminence to the lip of the round window niche (Fig. **90**).

Anson and Donaldson (1992) do not distinguish between the four tympanic sinuses. They use the term *sinus tympani,* but do not specifically subdivide into the smaller posterior tympanic sinus and the larger sinus tympani.

Facial recess. Inspection of the tympanic sinus through the facial recess, even when maximally opened in posterior atticotympanotomy, is difficult and often impossible. The view to the round window niche is, however, excellent. The first recess to be seen is the facial sinus, after drilling through the facial recess, leaving a bony bridge—a buttress (Nelson 1983)—posterior to the short process of the incus running between the tympanic ring and the lateral semicircular canal (Fig. **77**). Even after removal of the posterior buttress (Fig. **79**) and thinning of the bony annulus from within, although an excellent view to the short and the long process of the incus and the lateral part of the stapes can be obtained, the posterior tympanic sinus lies under the pyramidal eminence, and the sinus tympani cannot be viewed through the facial recess. If the tympanic sinus needs to be explored, for example in cholesteatoma or a deep retraction pocket extending into the sinus, the endaural approach through the ear canal should be used. Even after removal of the pyramidal eminence and all components of the styloid complex, the exposure is not always adequate, and more extensive removal of the bone covering the facial nerve often has to be performed (Fig. **91**).

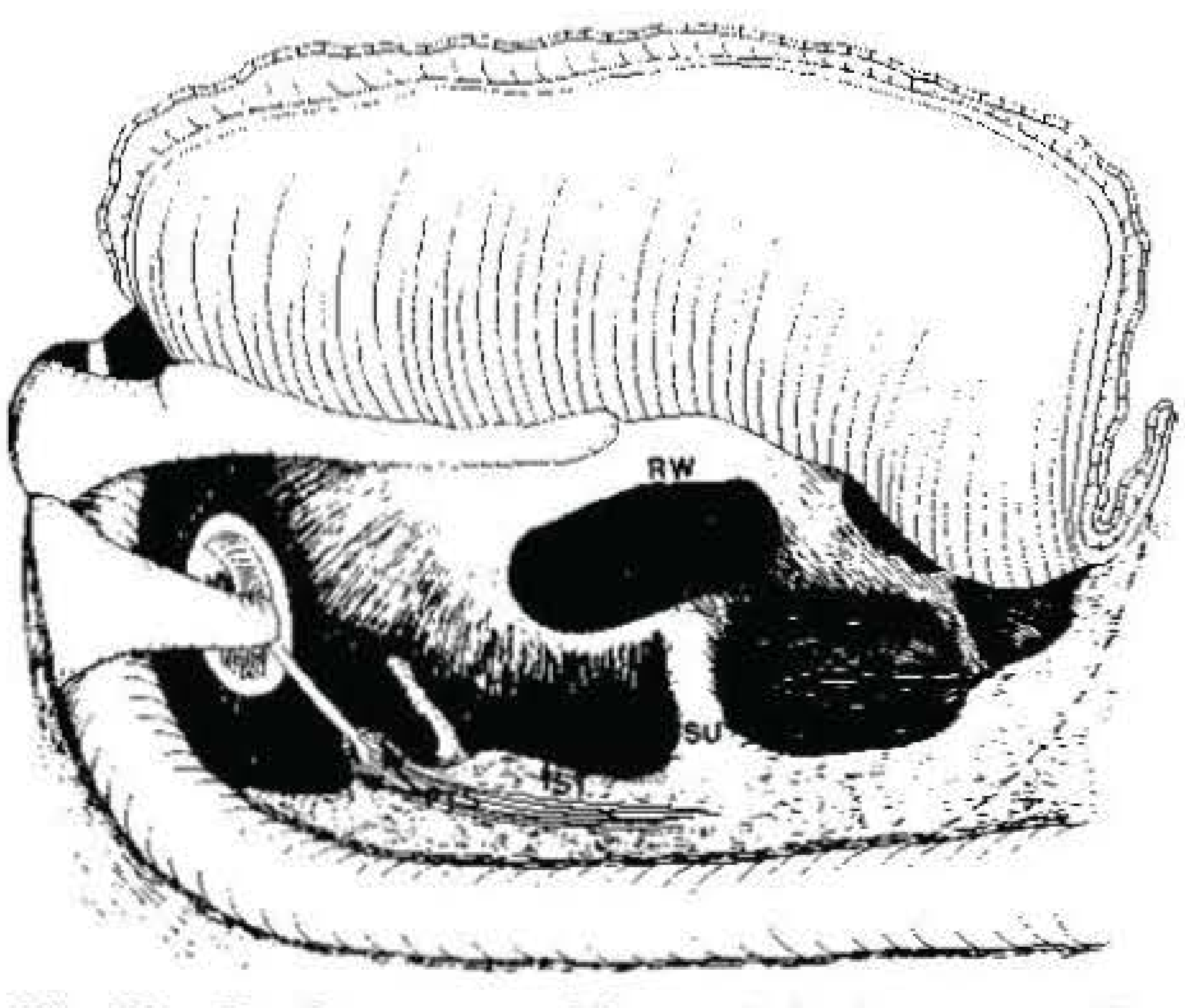


Fig. **91** Good exposure of the posterior tympanum after extensive removal of the bony annulus and all bone covering the facial nerve and the stapedius muscle. FTS: posterior tympanic sinus, ST: sinus tympani, SU: subiculum, RW: round window niche

Tympanic Diaphragm

Tympanic diaphragm is a term introduced by Proctor (1964) to define the obstacles within the tympanic isthmus and the attic. These obstacles are the tympanic folds and ligaments running between the surrounding bony structures and the incus body and malleus head. The tympanic diaphragm divides the attic from the mesotympanum. The tympanic diaphragm is a common site for impairment of ventilation to the antrum (Proctor 1971). Wullstein and Wullstein (1990) define this region as the second bottleneck of air flow, the first bottleneck being within the eustachian tube.

The most posterior parts of the posterior isthmus, as well as the anterior isthmus, are open for ventilation. All the other passages, according to Proctor, are more or less obstructed by the various mucosal folds that Proctor (1964) considers to be congenital structures and remnants of development. To explain the existence of the various folds, Proctor (1964) published very sophisticated and complicated figures illustrating the development of the middle ear spaces, but these figures are difficult to understand, and it is difficult to find any histological support for them.

Mucosal Folds

The folds divide the attic space into various compartments (Fig. **92**). They are located both in the lateral attic and the medial attic.

The *lateral incudal fold* connects the lateral attic wall and the body of the incus (Figs. **92, 93**). It extends posteriorly to the posterior incudal ligament.

The *anterior malleolar fold* (of von Tröltsch, 1873) is located between the anterior surface of the malleus head, the anterolateral bony wall of the attic, and the anterior malleolar ligament (Figs. **92, 93**).

The *superior malleolar fold* extends between the superior surface of the malleus head and the superior attic wall, and in the same plane as the superior malleolar ligament (Figs. **92, 93**).

The *superior incudal fold* extends, like the superior incudal ligament, between the superior aspect of the incus body and the superior attic wall (Figs. **92, 93**).

The *medial incudal fold* is located between the long process of the incus and the tendon of the stapedial muscle, as far as the pyramidal eminence (Figs. **92, 93**).

The *lateral malleolar fold* goes from the neck of the malleus up to the scutum (Fig. **92**), forming the superior border of Prussak's space.

The *interossicular fold* extends between the malleus handle and the long process of the incus (Fig. **93**).

The *anterior malleolar ligament* extends from the long process of the malleus toward the anterior attic wall (Fig. **92**).

The *tensor tympani fold* occupies the window between the tensor tympani tendon, the anterior bony plate of the attic wall, the tensor tympani eminence, and the anterior malleolar ligament (Fig. **92**).

The folds most commonly seen (Proctor 1989) are: 1) the tensor tympani fold, 2) the lateral incudal fold, 3) the medial incudal fold between the stapes crura and the incus (Fig. **92**), 4) the lateral malleolar fold, 5) the stapedial fold between the posterior crus of the stapes and posterior tympanic wall, following the stapes tendon and the pyramidal eminence (Fig. **92**), and 6) the obturator fold between the stapedial crura. The mucosal folds are very thin. They carry blood vessels to the ossicles, and Proctor (1989) considers them to be mesenteries.

Proctor (1964, 1989) claims that the tympanic mucosal folds, especially those in the anterior attic, are constant and are remnants of the development of the embryological sacs. According to Proctor (1989), ventilation of the attic never goes through the anterior attic, but only through the tympanic isthmus, i.e., posterior to the tensor tympani tendon. The anterior attic space, according to Proctor (1989), is blocked by the tensor tympani mucosal fold.

Ventilation through the anterior attic may be blocked in cases with adhesions, but Proctor does not present any evidence that this is the case in normal ears.

In the present author's opinion, there are several problems that need to be clarified by further research. There is no histological documentation in series including older fetuses and prematures showing that the development of mucosal folds takes place in the way described by Proctor (1964) in drawings. Proctor refers to the study by Hammar (1902), but this study is not based on the gestation period between the fifth and ninth months.

It is the present author's opinion that the folds may be sequelae of previous infection or inflammation of the middle ear, specifically either chronic secretory otitis media or acute suppurative otitis media, which are both very common during infancy or early childhood (Tos 1984, Stangerup and Tos 1985). In such cases, the folds are postinflammatory adhesions. The common finding of a fold does not mean that it is a congenital fold; it could just as easily be an adhesion. Aimi (1971, 1978) studied 300 fresh temporal bones exposing the attic, and found at

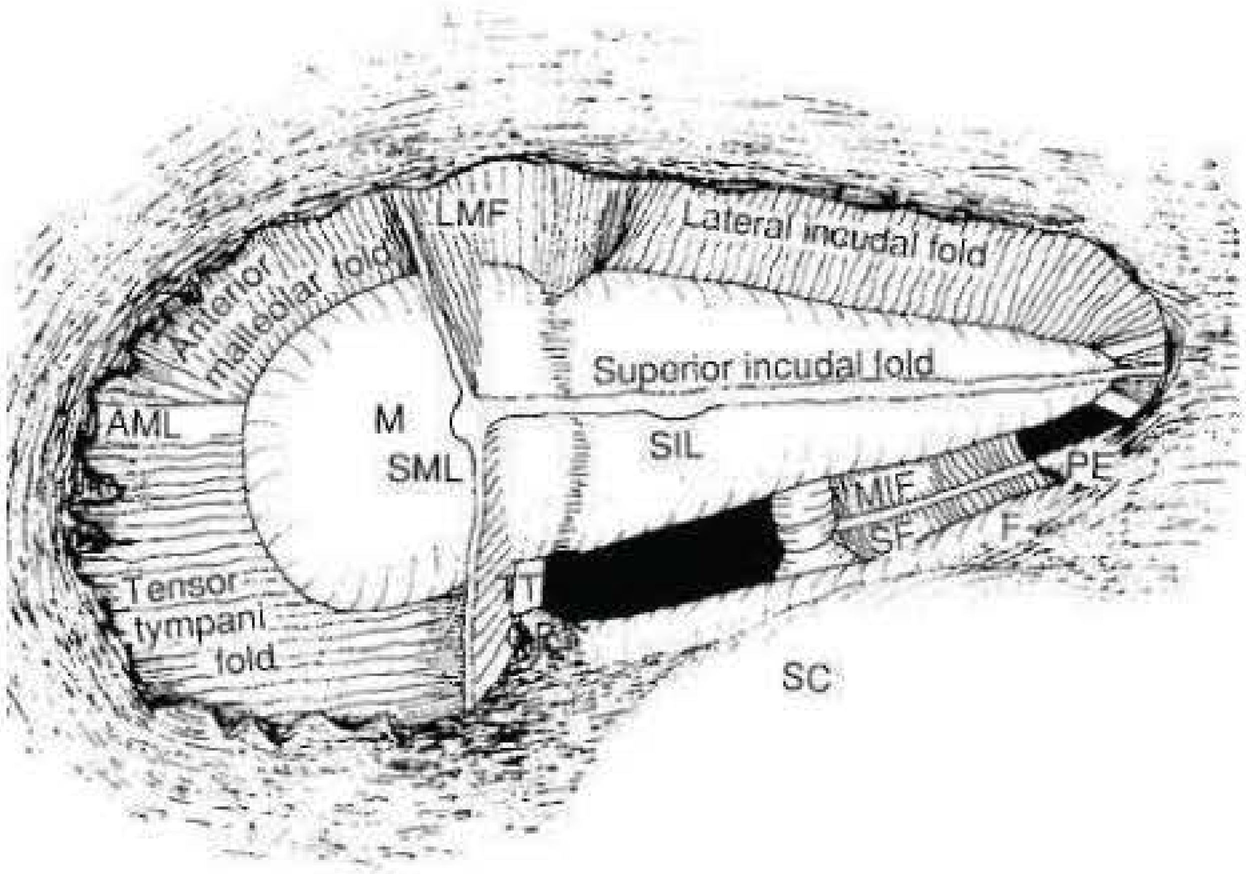


Fig. **92** **The mucosal folds, according to Proctor (1989)**, seen from above in the attic. In the lateral attic, the anterior malleolar fold, lateral malleolar fold (LMF), and lateral incudal fold, and in the medial attic, the tensor tympani fold, are illustrated. In the anterior tympanic isthmus lies the medial incudal fold (MIF) and the stapedial fold (SF). AML: anterior malleolar ligament; M: malleus head; SML: superior malleolar ligament; SIL: superior incudal ligament; CP: cochleariform process; F: facial nerve; PE: pyramidal eminence; SC: lateral semicircular canal; TT: tendon of the tensor tympani muscle

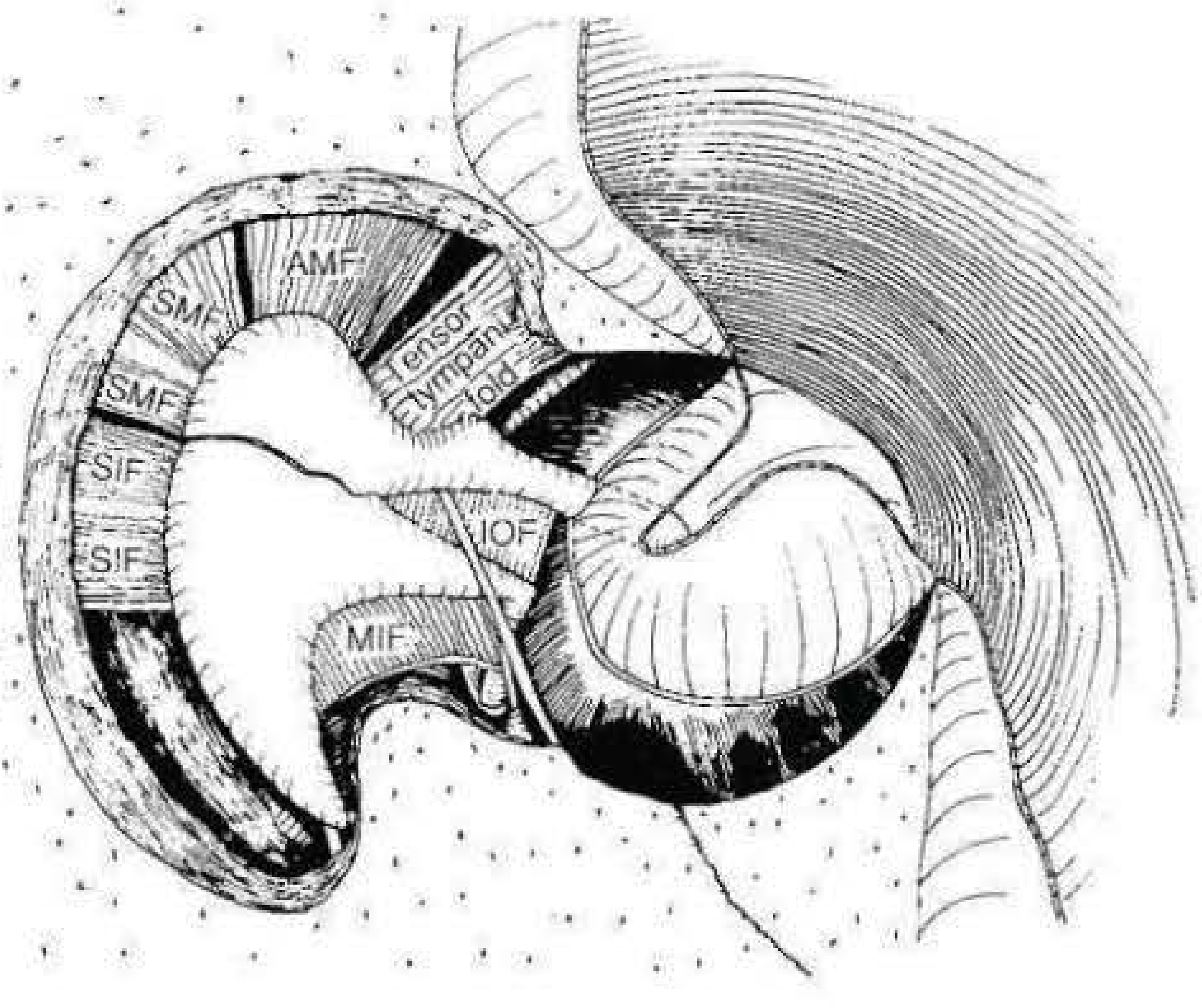


Fig. **93** **Mucosal folds in the attic**, opened as in atticotomy with removal of the bridge, exposing the entire lateral attic and the ossicles. The fibrous annulus is detached from the bony annulus posteriorly, superiorly, and anteriorly. SIF: superior incudal fold; SMF: superior malleolar fold; AMF: anterior malleolar fold; tensor tympani fold; MIF: medial incudal fold; IOF: interossicular fold, situated between the malleus handle and the long process of the incus. The posterior incudal ligament is seen at the incudal fossa, and the superior incudal ligament, superior malleolar ligament, and anterior malleolar ligament are also visible least some folds in most ears. He concluded that differentiation between hyperplastic mucosal folds and inflammatory webs is not easy. He also found considerable variation of mucosal folds in middle ears behind an intact tympanic membrane, and extensive folds in pathological conditions.

There are several reasons for the scepticism of the present author that the many folds are of congenital origin. In our quantitative histological studies of the middle ear mucosa in middle ears with normal ear drums, mucosal folds have been found in many cases. However, histological investigation of these folds revealed mucus glands, which is definitive proof that such folds are pathological structures or adhesions (Bak-Pedersen and Tos 1973, Tos 1974b). In the middle ear mucosa, mucus glands were found in 95% of cases, showing that even so-called normal middle ears have had disease in childhood, probably chronic secretory otitis media or acute suppurative otitis media. In our epidemiological studies of otherwise healthy children followed with tympanometry and otomicroscopy from birth to school age, we found that at least 90% of children have had secretory otitis at least once, about 50% have had it several times, and about 30% have suffered severe and long-lasting secretory otitis (Tos 1984). The common histological changes seen in normal temporal bones thus represent the documented sequelae of chronic secretory otitis media or acute suppurative otitis media. Adhesions in the attic are, in the author's opinion, much more common than the "congenital" mucosal folds described by Proctor (1989), which are the common sequelae of infection during childhood.

Prussak's Space

Prussak's space lies between Shrapnell's membrane and the lateral malleolar ligament (Fig. **94**). The medial border is formed by the short process and neck of the malleus, and the lateral border is the bony annulus of the Shrapnell's membrane region. From the neck of the malleus, the anterior malleolar fold and anterior ligament arise, demarcating Prussak's space anteriorly. Ventilation of Prussak's space is only possible posteriorly above the posterior malleus fold (Fig. **84**), which arises together with the posterior malleolar ligament from the posterior aspect of the malleus neck, and attaches to the posterior bony annulus. Between the posterior malleolar fold and the fibrous annulus, and related to the most superior part of the pars tensa, a small pouch, the von Tröltsch posterior malleus pouch, is located (Fig. **95**). The ventilation of the attic proceeds, according to Proctor, from the eustachian tube, around the tendon of the tensor tympani muscle, and through the anterior tympanic isthmus (Fig. **96**); and from here the anterior and superior attic and antrum are ventilated.

Cholesteatoma from the Shrapnell's membrane region may slip into Prussak's space and develop anterior to the malleus handle. It can remain hidden for a long time, and this gives Prussak's space its clinical importance.

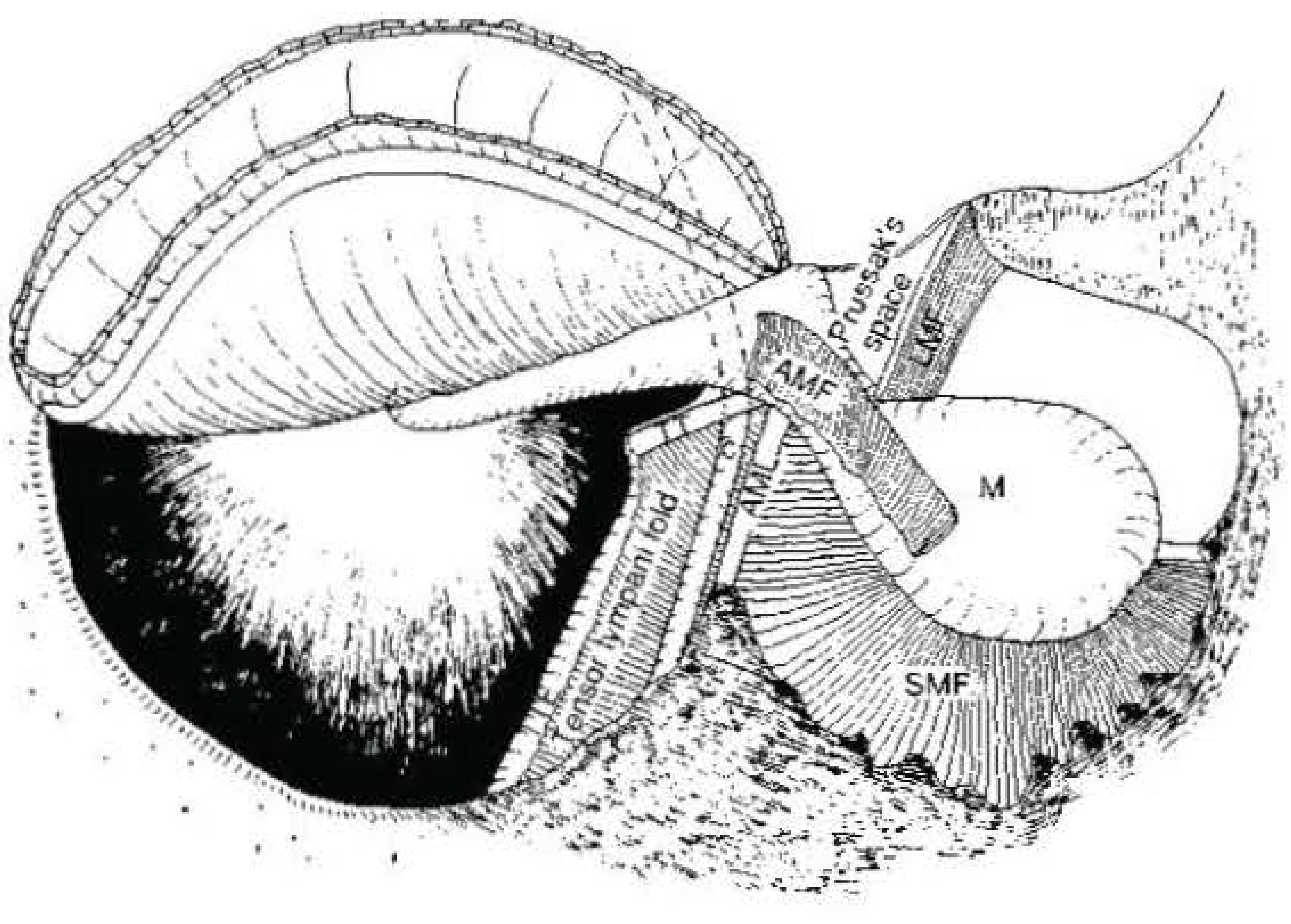


Fig. **94** Anteroposterior view of the mucosal folds in the anterior attic and protympanum with anterior tympanotomy showing **Prussak's space** between Shrapnell's membrane and the lateral malleolar fold (LMF). The anterior malleolar fold (AMF) arises from the neck of the malleus. The tensor tympani fold is located between the tendon of the tensor tympani muscle (TT), the anterior malleolar ligament (AML) and the tensor tympani muscle eminence (TTE). The superior malleolar fold (SMF) can extend between the anterior malleolar ligament and the superior malleolar ligament. C: chorda tympani

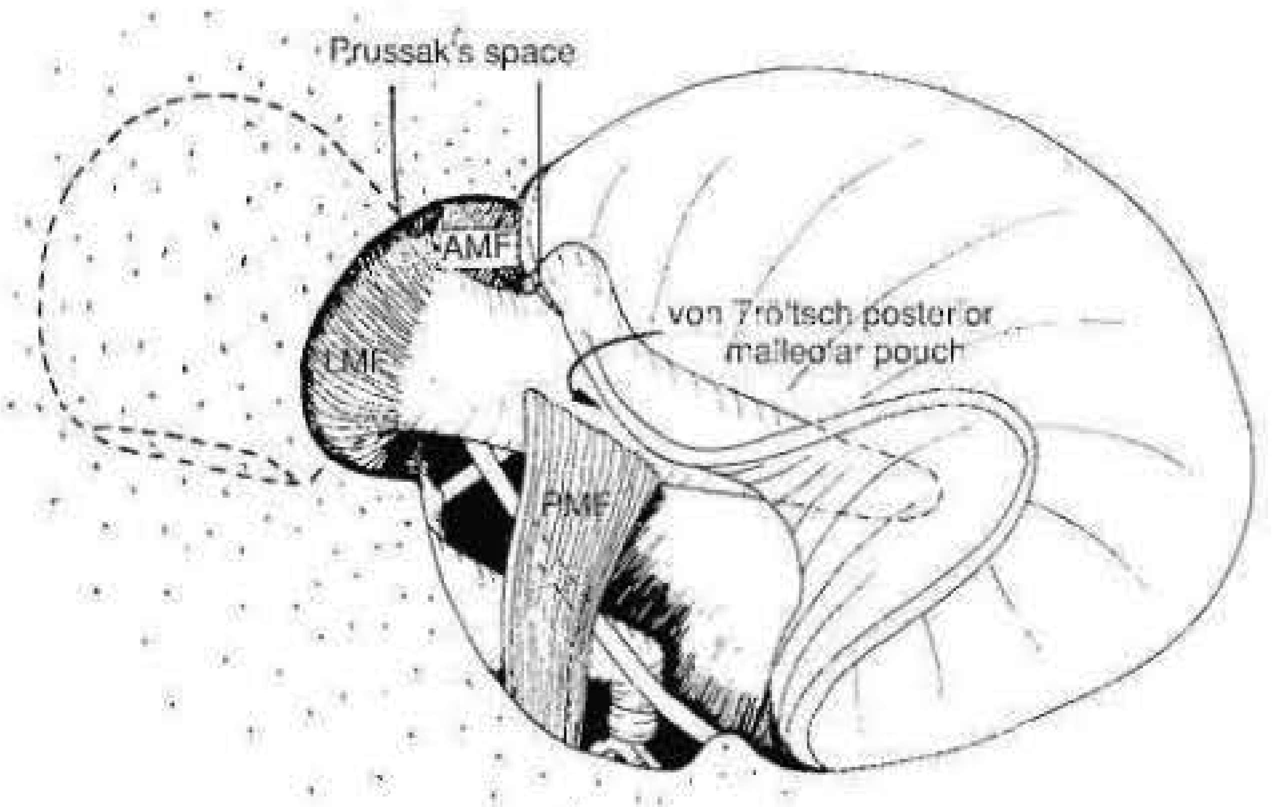


Fig. **95** **Prussak's space**, lying between the lateral malleolar fold (LMF), anterior malleolar fold (AMF), and the neck of the malleus. The von Tröltsch posterior malleolar pouch is located between the drum and the posterior malleolar fold with the ligament (PMF). The tympanic cavity is opened with a small superior and posterior tympanotomy

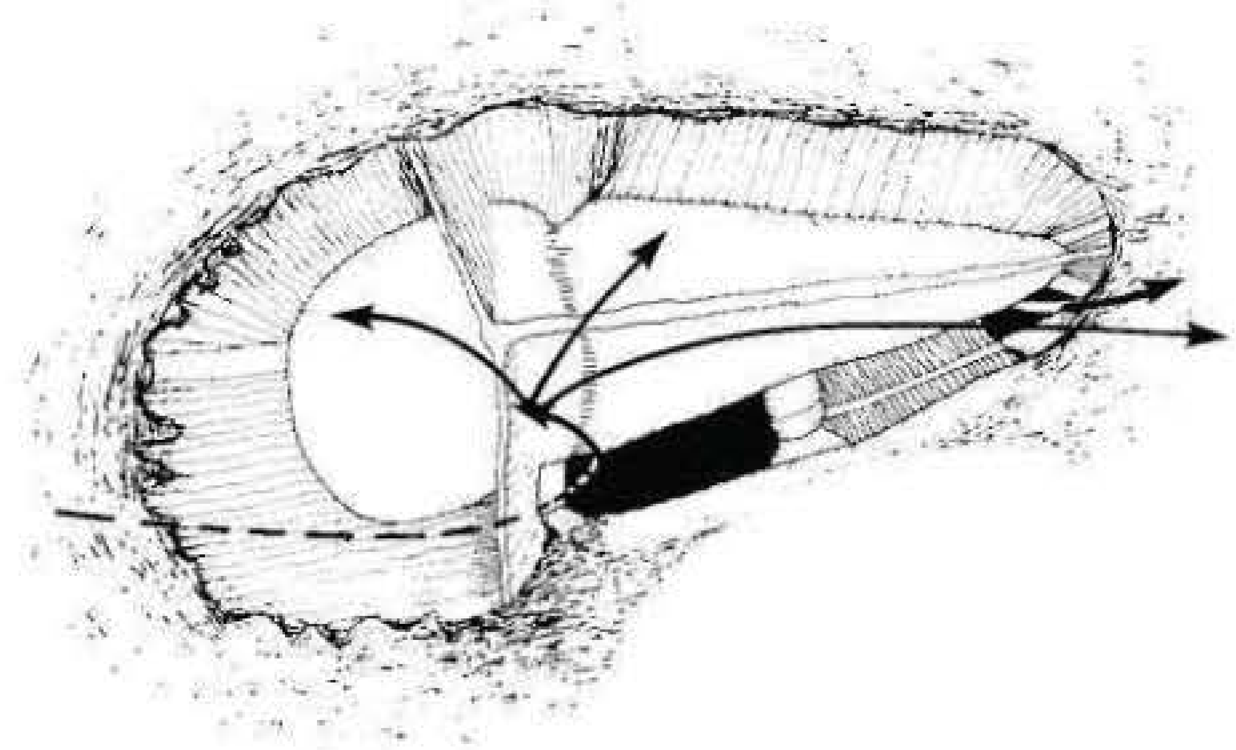


Fig. **96** **Ventilation of the attic and antrum**, according to Proctor (1989). From the eustachian tube, the ventilation runs along the eminence of the tensor tympani muscle, through the anterior tympanic isthmus on the superior surfaces of the malleus head and incus body, and further along the incus to the lateral attic, aditus ad antrum, and antrum. There is also some ventilation through the posterior tympanic isthmus (small arrow)

Mesotympanum

The upper portion of the tympanic cavity is called the mesotympanum. Its superior borders are the eminence of the horizontal facial canal, the cochleariform process, and the eminence of the tensor tympani muscle. The mesotympanum acts like a channel, providing ventilation to the attic, and allowing air to go from the eustachian tube past the eminence of the tensor tympani through the tympanic isthmus (Fig. **96**). Posteriorly lie the posterior tympanic sinus and the stapes. Inferiorly, the mesotympanum opens over the promontory, and anteriorly toward the eustachian tube (Fig. **97**). The tensor tympani muscle is attached to the bony part of eustachian tube at the tubal isthmus, as well as within its semicanal. It becomes a tendon at the cochleariform process, turns a right angle, and continues laterally toward the malleus handle (Fig. **98**).

Just medial to the cochleariform process and the tendon of the tensor tympani muscle, Jacobson's nerve (or the tympanic nerve) exits the tympanic cavity to continue as the lesser superficial petrosal nerve toward the greater petrosal nerve, on the surface of the petrous bone to the otic ganglion. The tympanic nerve arises from the glossopharyngeal nerve, and enters the tympanic cavity deep in the hypotympanum between the carotid artery and the internal jugular vein (Fig. **98**).

The lateral wall of the mesotympanum is made up of the drum with the chorda tympani, the malleus and incus, and the anterior malleolar ligament

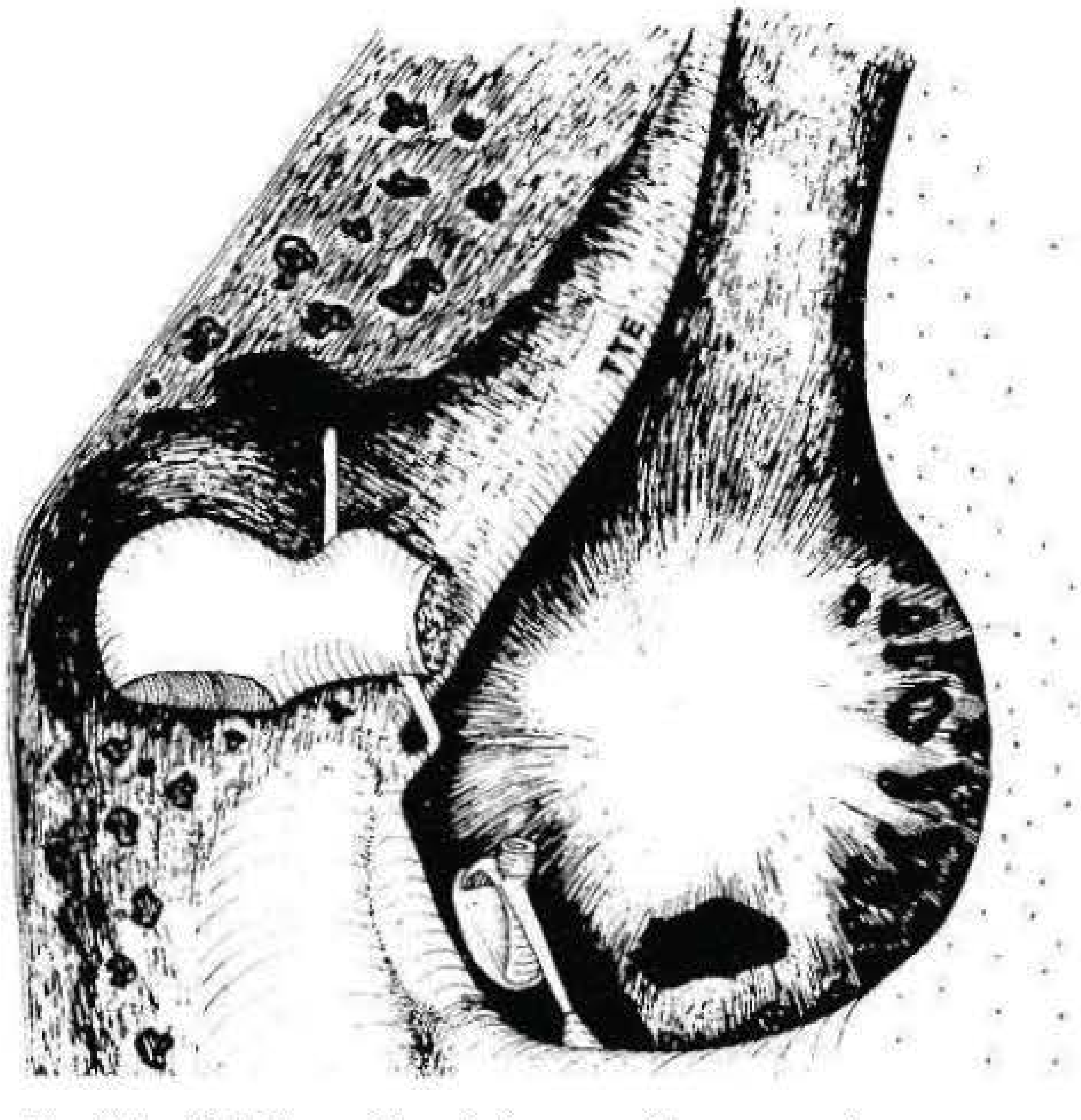


Fig. **97** **Relationship between the mesotympanum and the attic**, in a canal wall–down mastoidectomy situation with preserved malleus head. The eminence of the tensor tympani muscle (TTE) extends from the cochleariform process toward the isthmus of the Eustachian tube. The medial surface of the neck of the malleus is connected with the tendon of the tensor tympani muscle. The relatively smooth groove, without any obstacles, air cells, od folds, is visible in the mesotympanum and between the eminence of the tensor tympani muscle and the medial wall of the eustachian tube. The groove continues to the stapes region and to the anterior tympanic isthmus

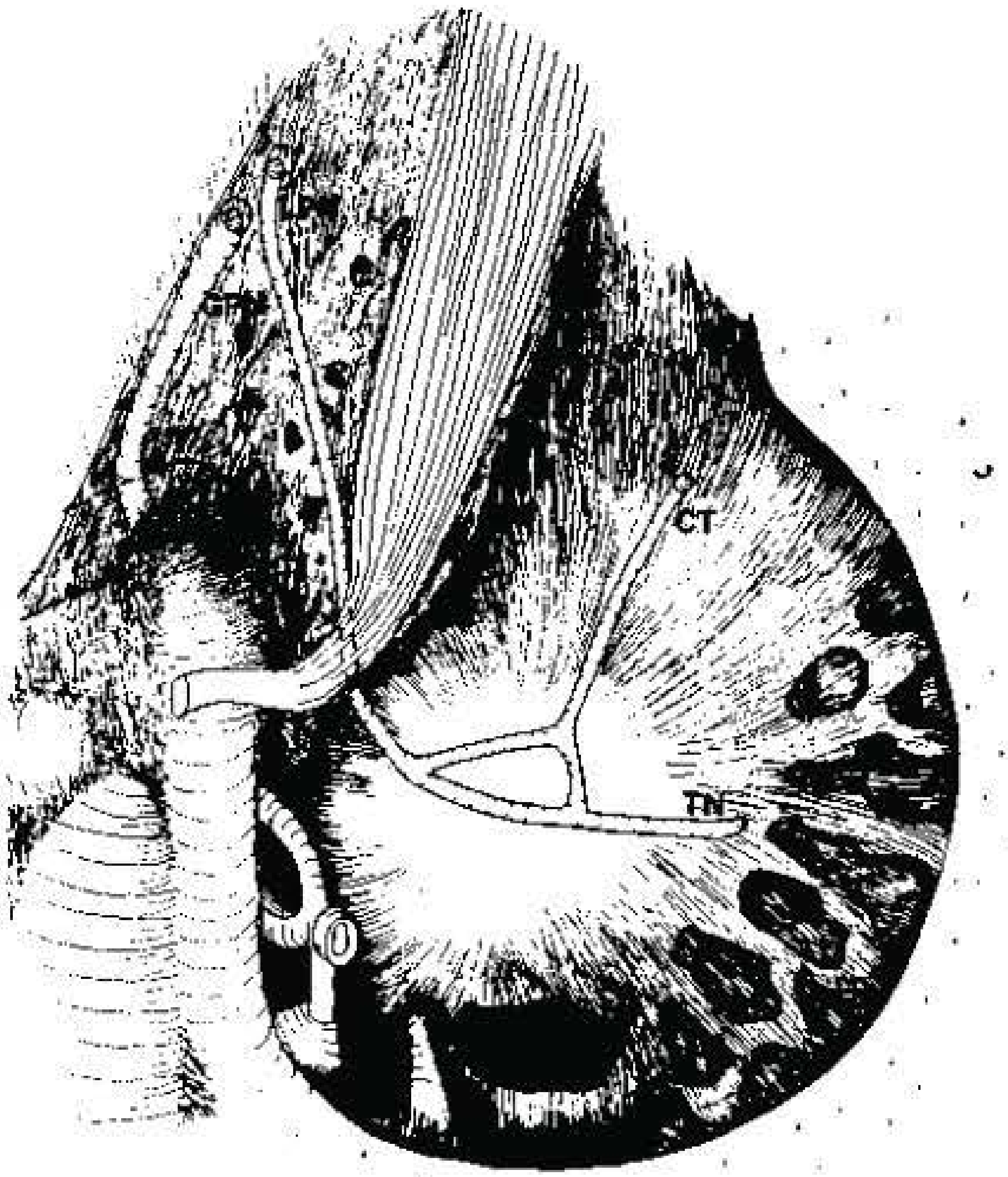


Fig. 98 **Medial aspect of the tympanic cavity**. The bone from the lateral aspect of the semicanal of the tensor tympani muscle is removed, exposing the muscle and the tendon running through the cochleariform process. Under the tendon, the tympanic nerve (TN) exits the tympanic cavity and continues toward the surface of the petrous bone as the lesser petrosal nerve (LPN). The tympanic nerve enters the tympanic cavity deep in the hypotympanum, and usually runs in a sulcus on the promontory. Sometimes the tympanic plexus is clearly visible, with the caroticotympanic nerve (CT). The horizontal part of the facial nerve emerges at the cochleariform process toward the surface of the pyramid, becoming the geniculate ganglion. From here, the greater petrosal nerve (GPN) exits, passing through a hiatus on the surface of the pyramid

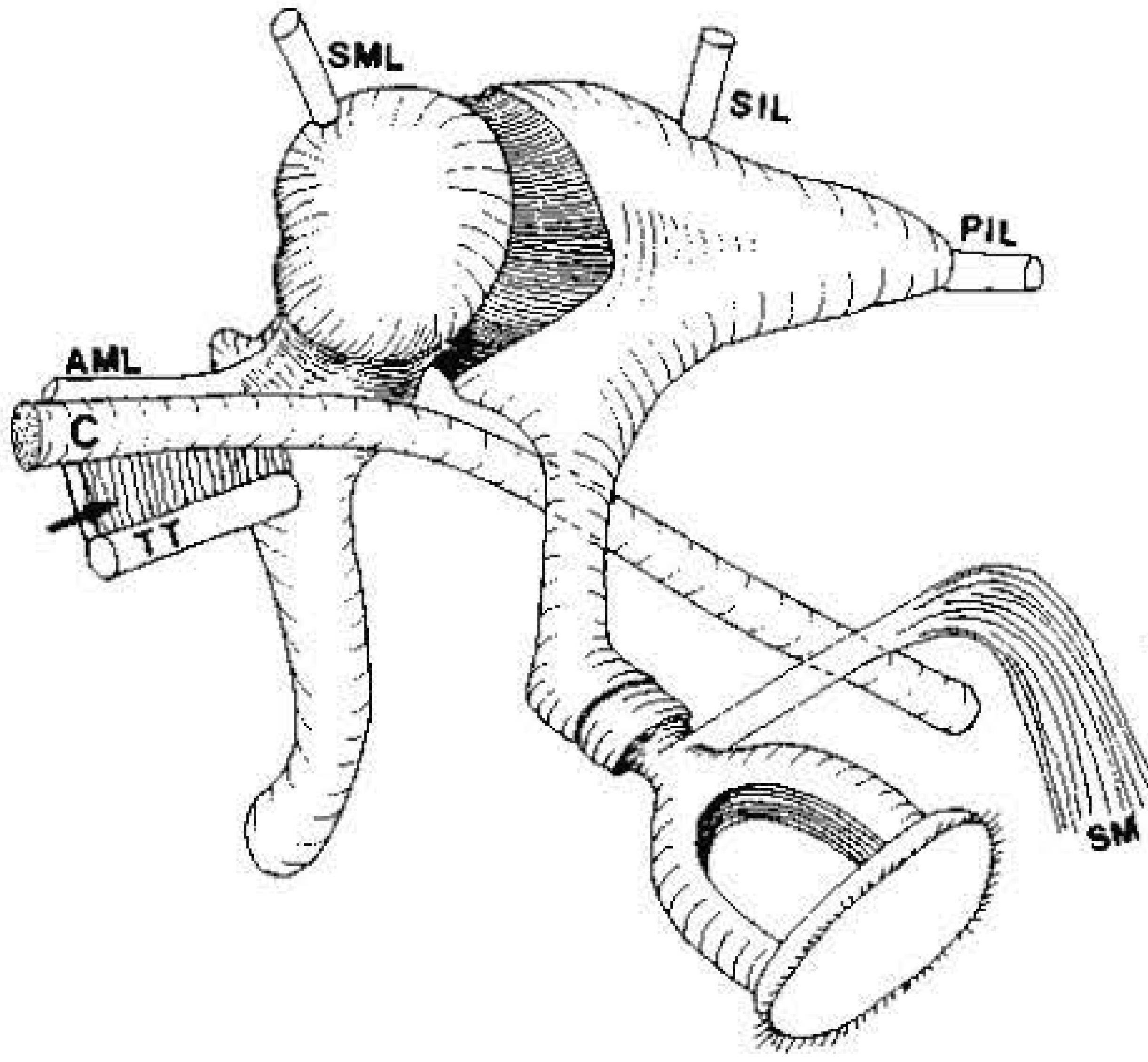
(Fig. **99**). The eminence of the tensor tympani muscle makes an angle with the horizontal part of the facial canal, which emerges at the cochleariform process to continue medially toward the geniculate ganglion and the greater petrosal nerve (Fig. **98**). At the ganglion, the facial nerve makes a 70° angle, and passes around the superior semicircular canal within the fallopian canal toward the internal acoustic meatus.

The Tympanic Orifice of the Eustachian Tube

The tympanic orifice of the Eustachian tube is a large oval opening in the tympanic bone, surrounded by the medial and lateral walls of the Eustachian tube. The border between the tympanic cavity and the bony part of the Eustachian tube or the protympanum is most distinct on its floor, where the obliquely arising anterior wall of the tympanic cavity curves toward the inferior wall of the bony tube. The roof of the protympanum is composed of the bony semicanal for the tensor tympani muscle and the smooth conchal roof of the protympanum itself (Fig. **98**). Lateral to the roof of the protympanum is a channel through which the chorda tympani nerve and the narrow internal tympanosquamosal crest pass.

The lateral wall of the protympanum consists of a thin bony plate of the tympanic bone called the lateral lamina (Fig. **100**). This continues down as the lateral wall of the bony Eustachian tube. The medial wall consists of the thin bone of the carotid artery wall.

After passing below the undersurface of the neck of the malleus just superior to the attachment of the tendon of the tensor tympani muscle, the chorda passes anteriorly through the anterior attic, just medial to the anterior malleolar ligament, and enters the aperture of the petrotympanic fissure (the glaserian fissure) (Fig. **100**). It continues in the same channel onto the inferior surface of the temporal bone, and later joins the lingual nerve. Cleaning the anterior attic in order to enter the



◁ Fig. **99** **The lateral aspect of the mesotympanum**, showing the medial sides of the malleus and incus and their ligaments. Anteriorly, the anterior malleolar ligament (AML) and chorda tympani (C) are connected with the tensor tympani tendon (TT) through the tensor tympani mucosal fold (arrow). LML: superior malleolar ligament; SIL: superior incudal ligament; PIL: posterior incudal ligament; SM: stapedial muscle, with its tendon

Eustachian tube and the epitympanic sinus and pretubal recess should take place medial to the chorda in order to avoid damaging it.

The *pretympanic recess* is a blind-ending bony sac formed within the lateral lamina of the Eustachian tube, and is entered when performing an anterior tympanotomy after elevating the anterior fibrous annulus and drilling away the relatively thin bony fibrous annulus and lateral wall of the Eustachian tube toward the isthmus of the tube (Fig. **101**). During bougienage of the Eustachian tube, which the author performs routinely in patients with a negative preoperative Valsalva maneuver a soft rubber bougie may enter the pretympanic recess, suggesting stenosis of the Eustachian tube. Another attempt at bougienage directed toward the medial wall of the tube and toward the eminence of the tensor tympani muscle usually succeeds, and the bougie can be passed through the Eustachian tube into the rhinopharynx without problems. In the inferior wall of the Eustachian tube peritubal air cells, or a continuation of the hypotympanic cells, may be found.

In cases of cholesteatoma invading the Eustachian tube and covering the lateral wall of the tube, the bone should be removed lateral to the tube (Fig. **101**) in order to visualize the mucous membrane of the lateral wall of the Eustachian tube and to remove the cholesteatoma along with the mucosa. This drilling can in fact extend deep toward the isthmus of the tube, since there are no important structures along the lateral wall of the tube. The carotid canal lies medial to the medial wall of the Eustachian tube.

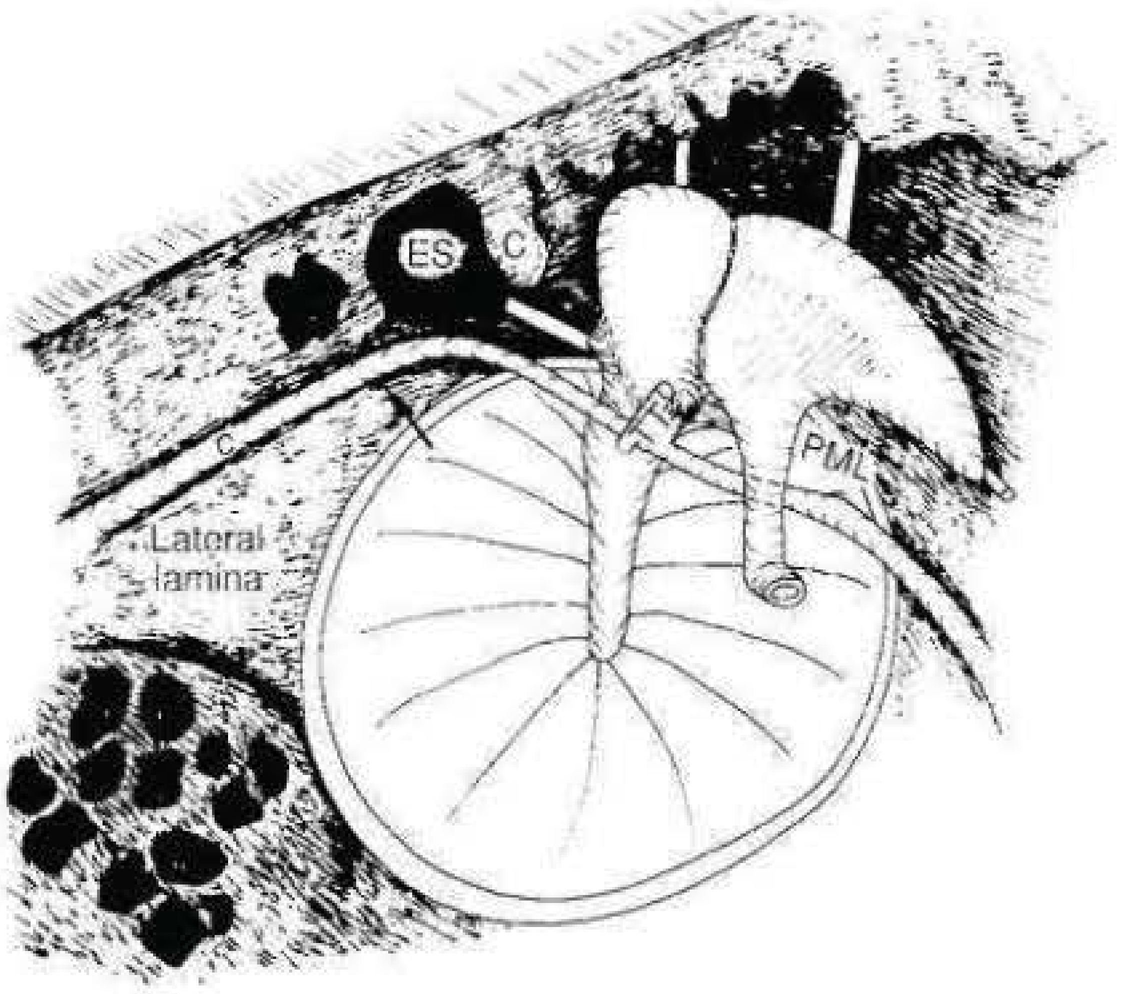


Fig. **100** **The lateral wall of the right tympanic cavity, the attic, the Eustachian tube, and the protympanum** have been removed and turned outward, allowing a mediolateral view and showing the course of the tympanic chorda through the petrotympanic fissure. The lateral part of the cog (C) and the epitympanic sinus (ES), are seen. The tympanic chorda enters the aperture (arrow) of the petrotympanic fissure and continues down anteriorly along the fissure and along the superolateral border of the Eustachian tube. In the anterior attic, the chorda is located medial to the anterior malleolar ligament. PML: posterior malleolar ligament; TT tendon of the tensor tympani muscle

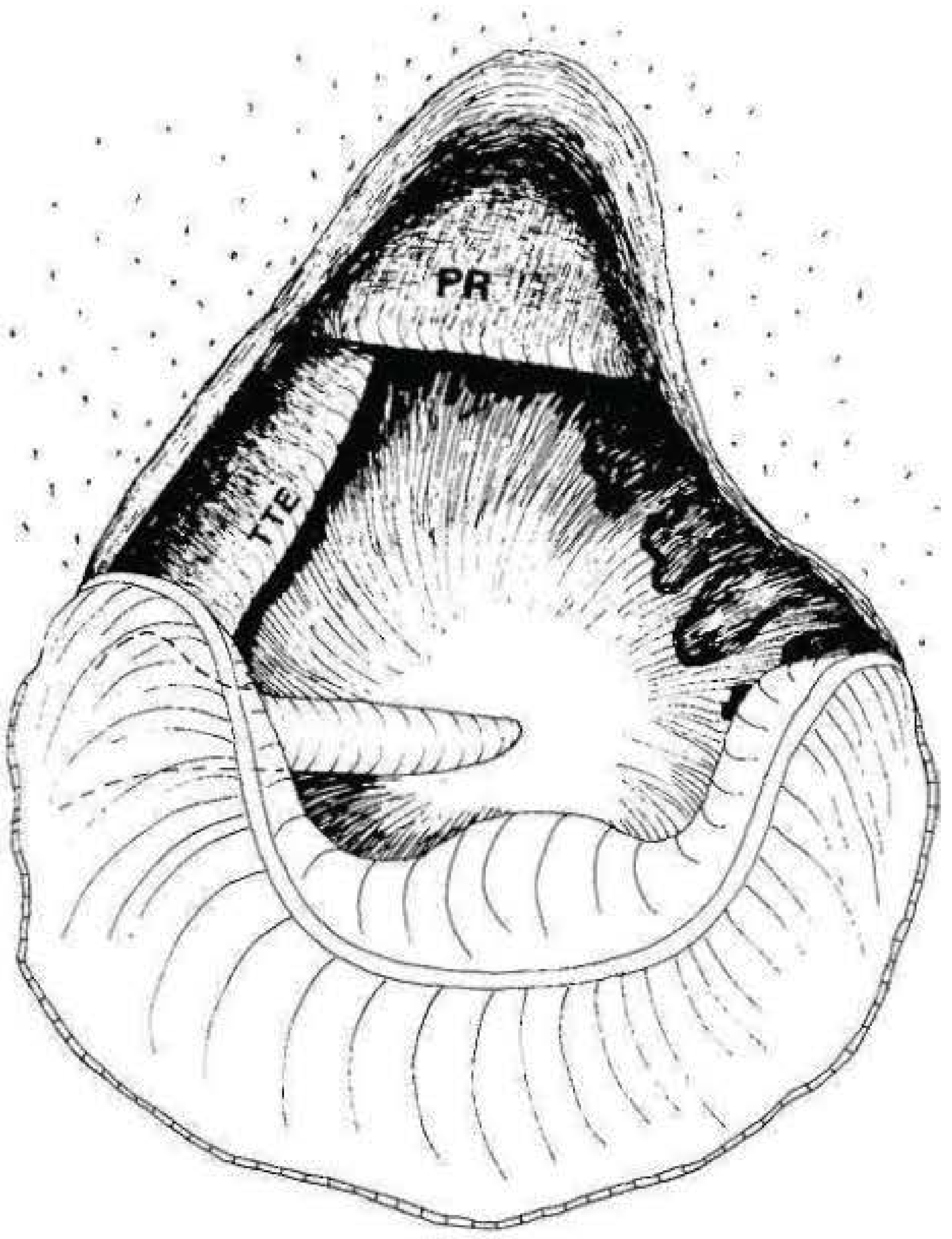


Fig. **101** **The pretympanic recess** (PR) seen in a large ▷ anterior tympnanotomy, with elevation of the fibrous annulus and drilling of the bony annulus and the lateral wall of the bony Eustachian tube. The pretympanic recess is a blind sac in the lateral wall. The Eustachian tube lumen is situated medial to the pretympanic recess. Superiorly, the eminence of the tensor tympani muscle (TTE) is seen, and inferiorly the air cells and bony septa, continuing toward the hypotympanum

Hypotympanum

The hypotympanum can be involved in tensa retraction cholesteatoma or sinus cholesteatoma. Retractions of the atrophic pars tensa often extend into the hypotympanum, involving the air cells lying inferior to the round window region and the promontory. The anatomy of the hypotympanum has became more important in skull base surgery, especially in glomus tumor surgery, but also in drainage of the petrous apex, which is performed through the hypotympanum and the lowest part of the tympanic cavity. The walls of the hypotympanum are formed mainly by the tympanic bone, but medially and inferomedially the tympanic bone meets the petrous part of the temporal bone. The outer wall of the hypotympanum is formed by the tympanic ring of the tympanic bone, and the superior wall is the promontory (Fig. **102**). These two structures are the only constant ones. The hypotympanum forms a regular bony groove that is demarcated by air cells of various sizes and by the bony septa of these cells (Fig. **103**). Its shape is also influenced by the protrusion of the jugular bulb into the tympanic cavity, which is found in 25% of ears (Savic and Djeric 1987). We found this, to be a superior position of the jugular bulb, with its dome located superior to the inferior border of the bony annulus in 45% of temporal bones (Turgut and Tos 1991 b), and indeed in 10% the bulb reached the level of the round window niche. The other structure lying anteromedially is the carotid canal, which forms the anteromedial wall in 26% of cases (Fig. **104**). In 74% of cases, the anteromedial wall is formed by the petrous bone.

The posterior wall is formed by an element of the styloid complex and the facial nerve canal. The floor separates the tympanic cavity from the jugular bulb (Fig. **105**). In cases with a high jugular bulb, the hypotympanum is significantly reduced, or even missing.

The anterior wall of the hypotympanum is formed by the petrous bone in 33% of cases. The height varies considerably. It is usually pneumatized, but sometimes compact, and from it air cells open into the hypotympanum, frequently extending into the infratubal pneumatic tract toward the apex of the pyramid of the temporal bone (Figs. **102–105**).

Within the hypotympanum, sinuses and recesses have been described. A posterior hypotympanic sinus may include deep cells posteroinferiorly within the hypotympanum (Fig. **106**). The anterior hypotympanic sinus goes toward the anterior cell tract, and can communicate with the petrous apex. In atelectatic ears, retraction of an atrophic drum into a hypotympanic sinus will sooner or later lead to a cholesteatoma due to impaired migration of keratin out of this type of retraction.

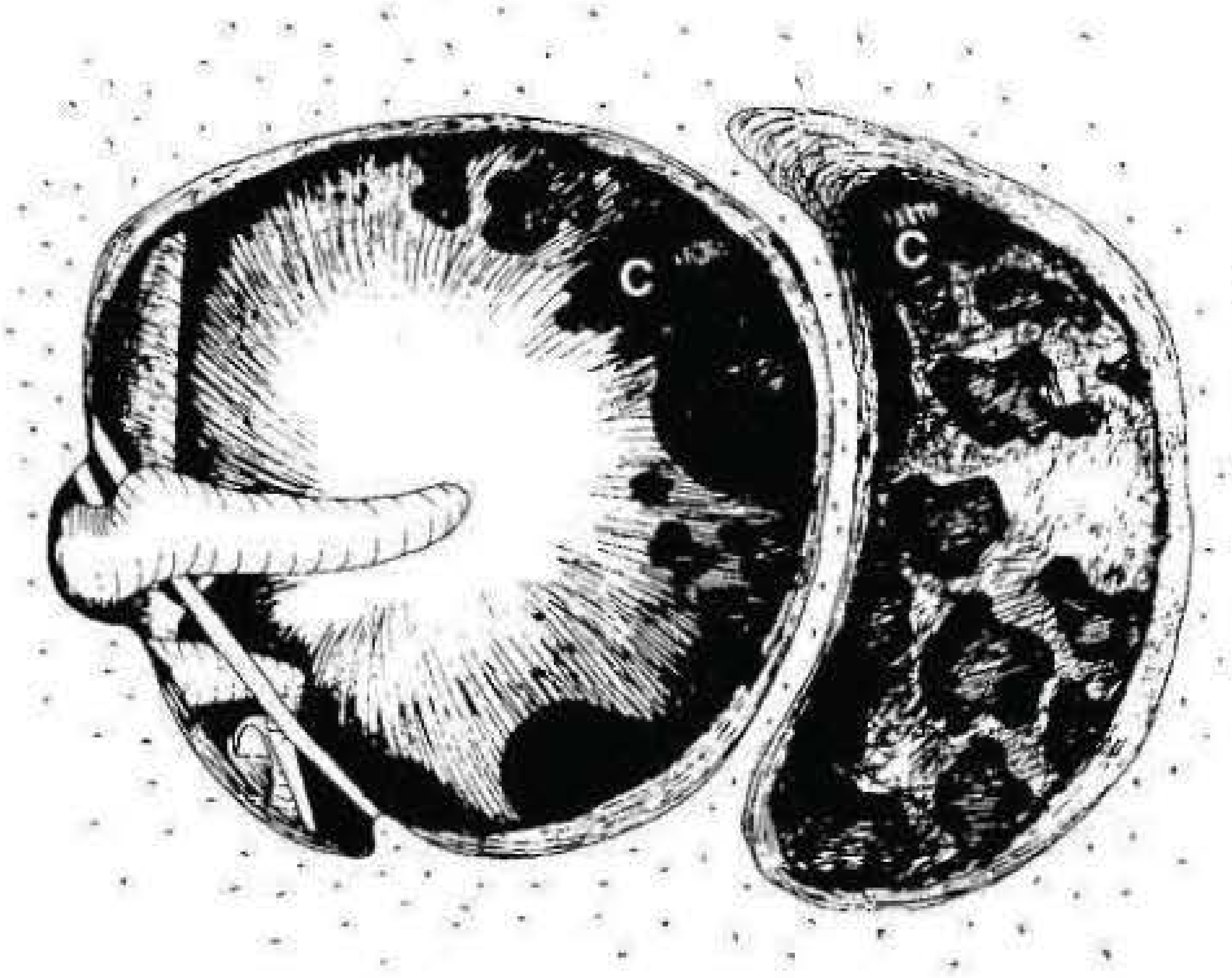


Fig. **102** **The hypotympanic air cells** extending deep into the hypotympanum. The edge of the bony annulus is drilled away all the way around the tympanic ring. The tympanic bone inferior to the tympanic ring is removed, exposing large hypotympanic cells. The canal of the carotid artery (C) is located anteriorly in the hypotympanum. Posterior to the carotid artery, there are deep cells, leading to the petrous apex

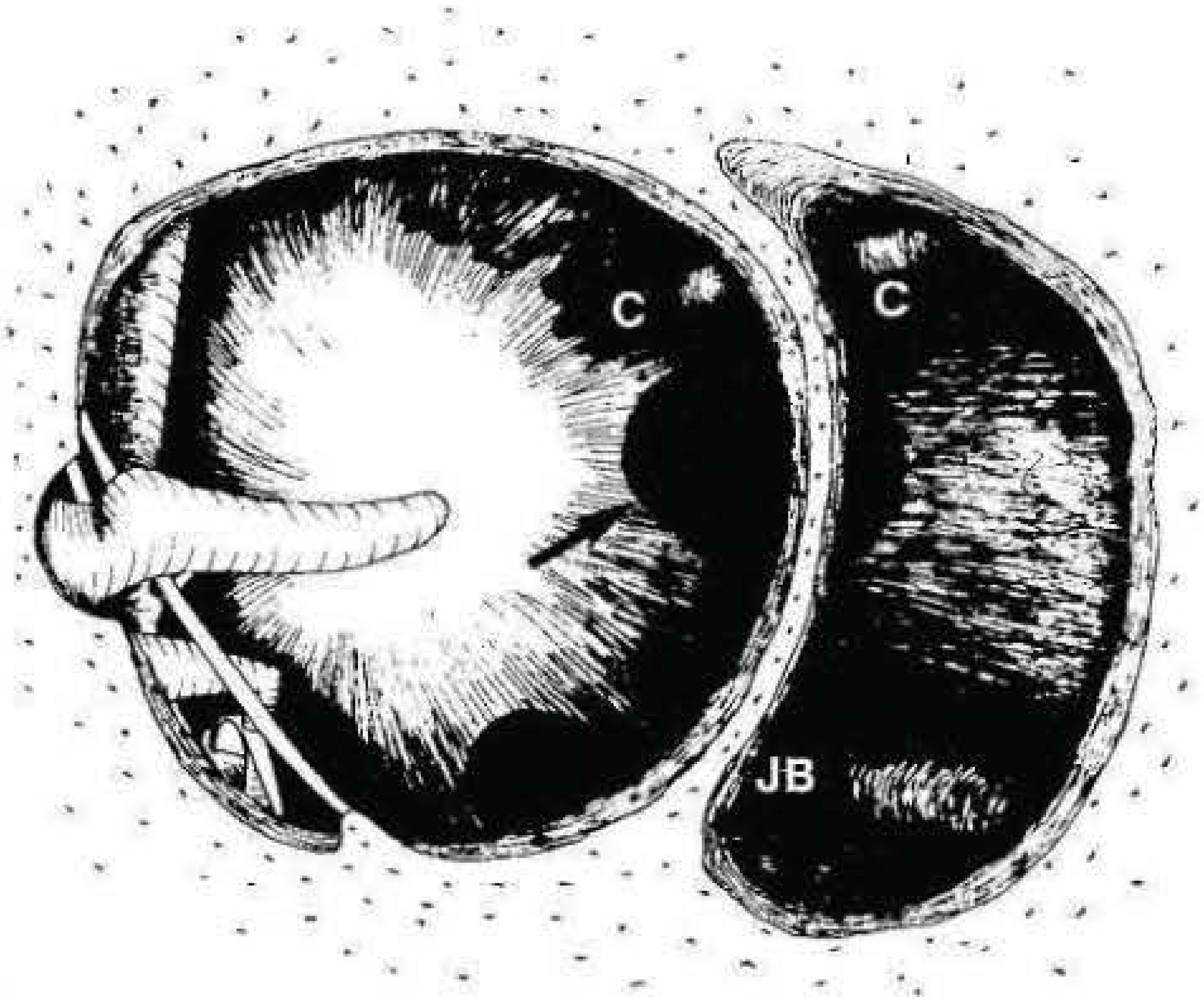


Fig. **103** Further removal of the air cells and bony septa in the hypotympanum exposes the carotid artery (C) and the internal jugular vein (JV) in a case with a high position of the jugular bulb (JB). Between the two vascular structures, and inferior to the promontory, large air cells may lead to the apex of the pyramid (arrow)

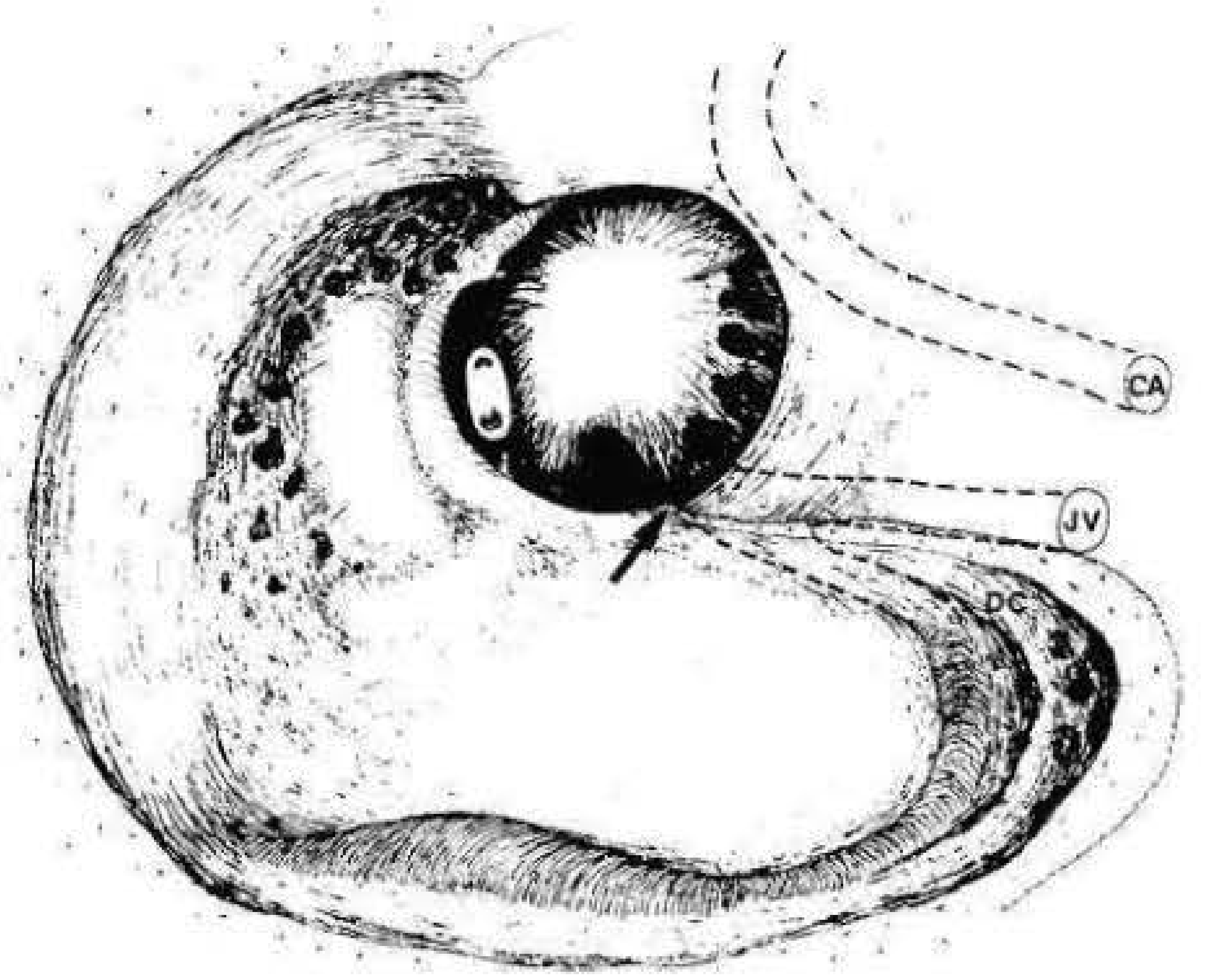
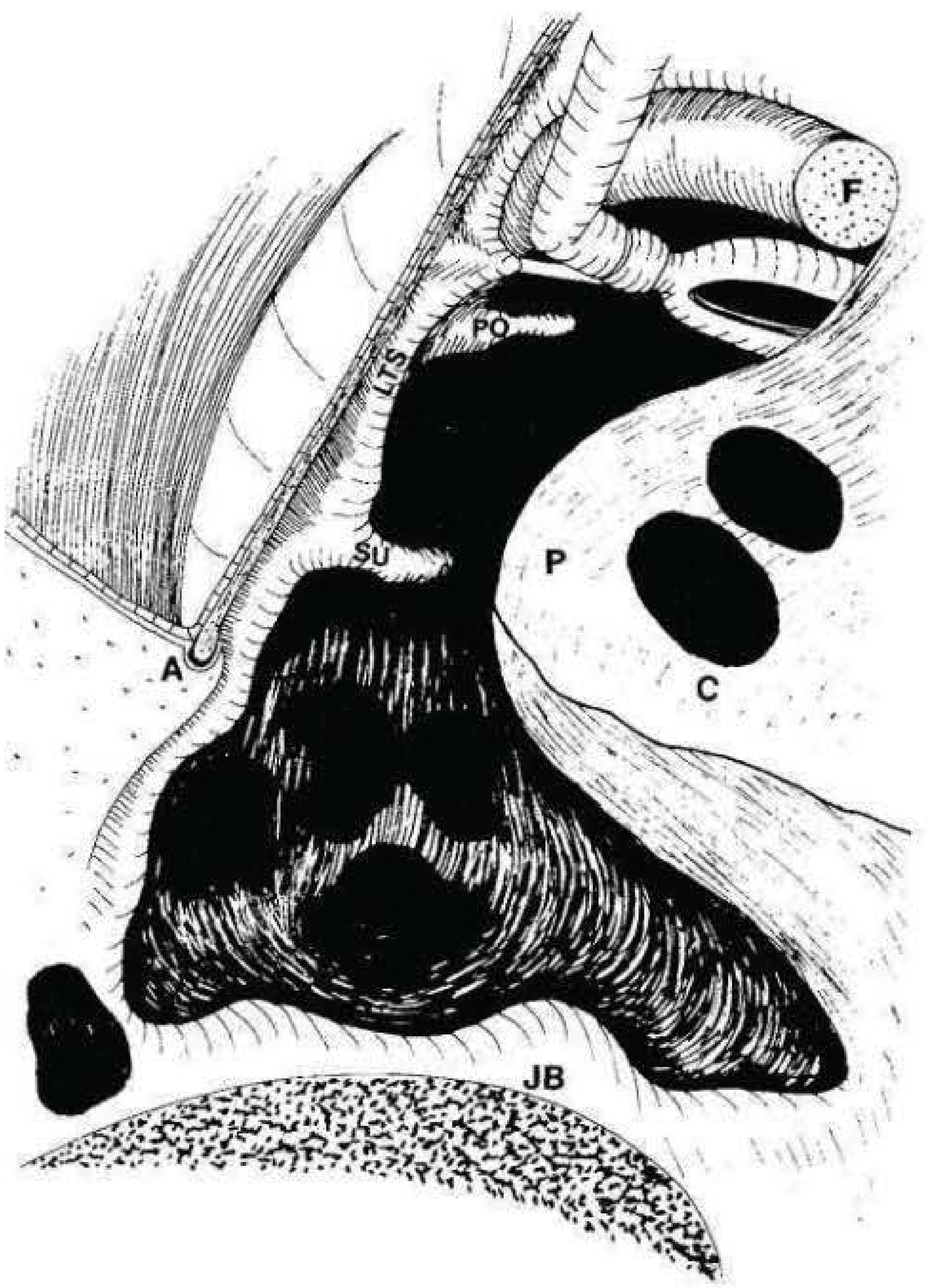
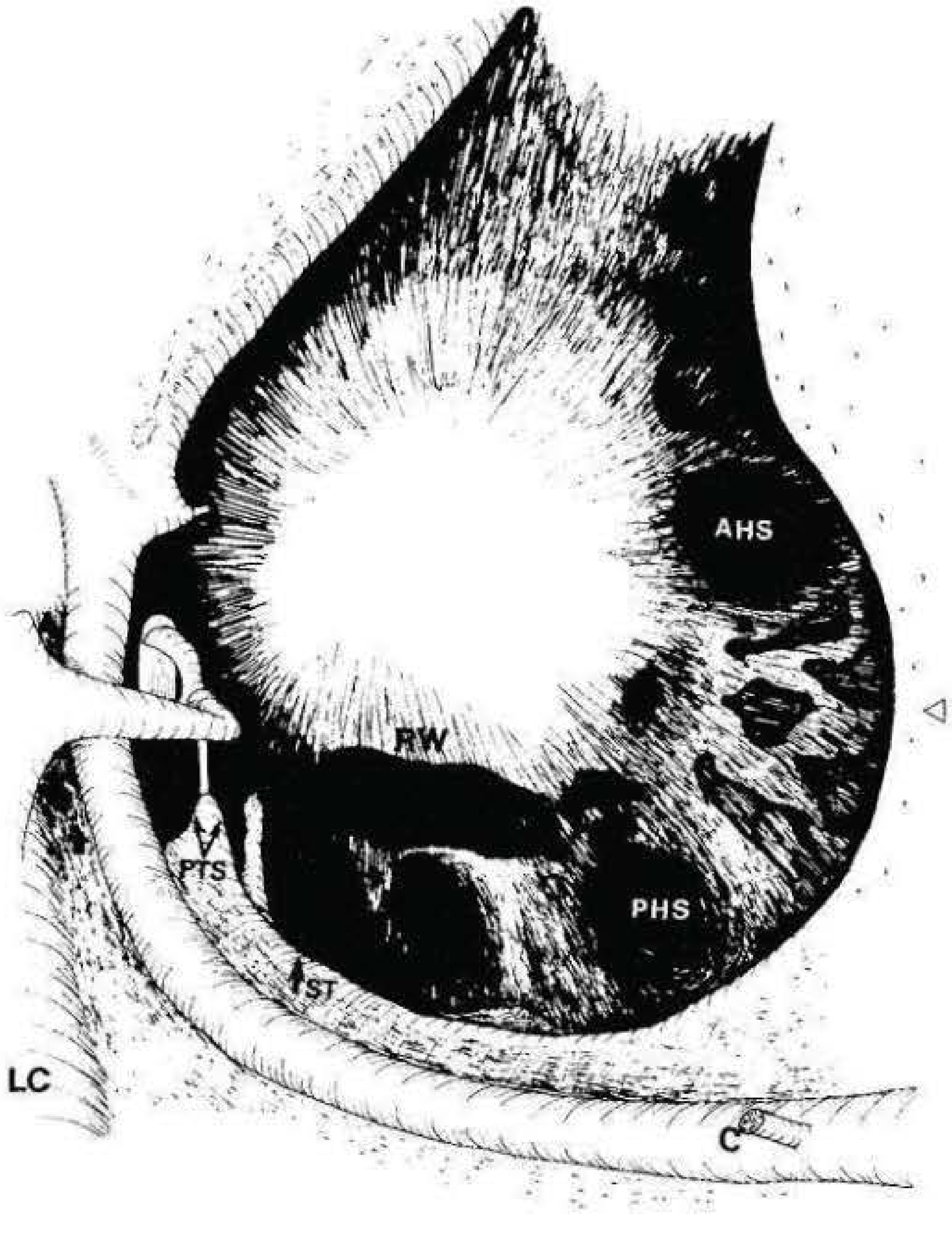


Fig. **104** **A canal wall–down mastoidectomy situation** with a low facial ridge, indicating the course of the carotid artery (CA) and internal jugular vein (JV) deep in the temporal bone. The dome of the high jugular bulb is at the level of the round window niche (arrow). The course of the sigmoid sinus under the facial nerve and its connection to the jugular bulb are indicated by dashed lines. DC: diagastric crest



△

Fig. **105** **Frontal section through the promontory** (P) **and facial nerve** (F) **anterior to the stapes,** showing the posterior aspect of the hypotympanum and its connection to the posterior tympanum. Deep air cells extend down to the dome of the jugular bulb (JB) far inferior to the inferior bony annulus (A). The promontory (P) with the cochlea (C) is cut. The lateral tympanic sinus (LTS) under the posterior bony annulus and the deep sinus tympani inferior to the ponticulus (PO) and superior to the subiculum (SU) are indicated. Inferior to the subiculum, large air cells extend deep down under the basal turn of the cochlea (C)



◁ Fig. **106** **The posterior hypotympanic sinus** (PHS) and **anterior hypotympanic sinus** (AHS) in a canal wall–down mastoidectomy situation with removal of the facial ridge, bony annulus, and all the tympanic bone down to the vertical segment of the facial nerve, which is skeletonized. The inferior bony annulus is drilled away, exposing the hypotympanic cells of the protympanum. Extensive drilling around the posterior tympanum inferior to the pyramidal eminence, and removal of the bone surrounding the stapedial muscle and the facial nerve, provides excellent visualization of the posterior tympanic sinus (PTS) and sinus tympani (ST). LC; lateral semicircular canal; C: the exit of the chorda; RW: round window niche

The Facial Nerve

The facial nerve is the most important structure in both middle ear and inner ear surgery, as well as in skull base surgery. In middle ear surgery, the horizontal and vertical parts of the facial nerve are always closely related to the surgery. In acoustic neuroma surgery, the labyrinthine segment and the intrameatal and intracranial segment in the cerebellopontine angle are involved.

After leaving the pons, the seventh cranial nerve runs through the cerebellopontine angle (Fig. **107**). Anterior to the acoustic and vestibular nerves, it passes through the porus and internal acoustic meatus, and leaves the meatus anterosuperiorly at the fundus to pass through the meatal foramen into the Fallopian canal. The Fallopian canal begins at the floor of the fundus superior to the transverse crest, and anterior to Bill's bar (the vertical crest) it passes laterally and anteriorly towards the geniculate ganglion. It then turns in a 70–80° angle to form the first turn, or first genu. At the geniculate ganglion, the intermedius nerve leaves the facial nerve as the greater superficial petrosal nerve, running in an anterior direction on the superior surface of the petrous bone toward the sphenopalatine ganglion.

The facial nerve continues posteriorly for 10-12 mm as the horizontal, second or tympanic part of the facial nerve (Fig. **107**). At the same time, it is directed 70° laterally and 10° inferiorly in close proximity to the horizontal semicircular canal.

The horizontal portion of the facial nerve is visualized in any tympanoplasty lying between the cochleariform process and the pyramidal eminence at the second genu (external) (Fig. **108**). Here the facial nerve is often dehiscent, protruding out of its canal. At the cochleariform process, the horizontal part turns somewhat medially as it passes toward the geniculate ganglion, but the entire horizontal part of the nerve can be exposed during a mastoidectomy (Fig. **109**).

At the second genu, the facial nerve turns at an angle of 125° and runs as the third, vertical part or mastoid segment toward the stylomastoid foramen (Figs. **107, 108**). The vertical part is often exposed surgically. It commerces at the second or external genu, lying anterior to the lateral and posterior semicircular canals that form the medial wall of the facial recess. The chorda tympani arises from the lateral wall of the nerve (Fig. **109**). There are no other structures inferior to the posterior semicircular canal, and the entire nerve can be exposed from all sides as far as the styloid foramen.

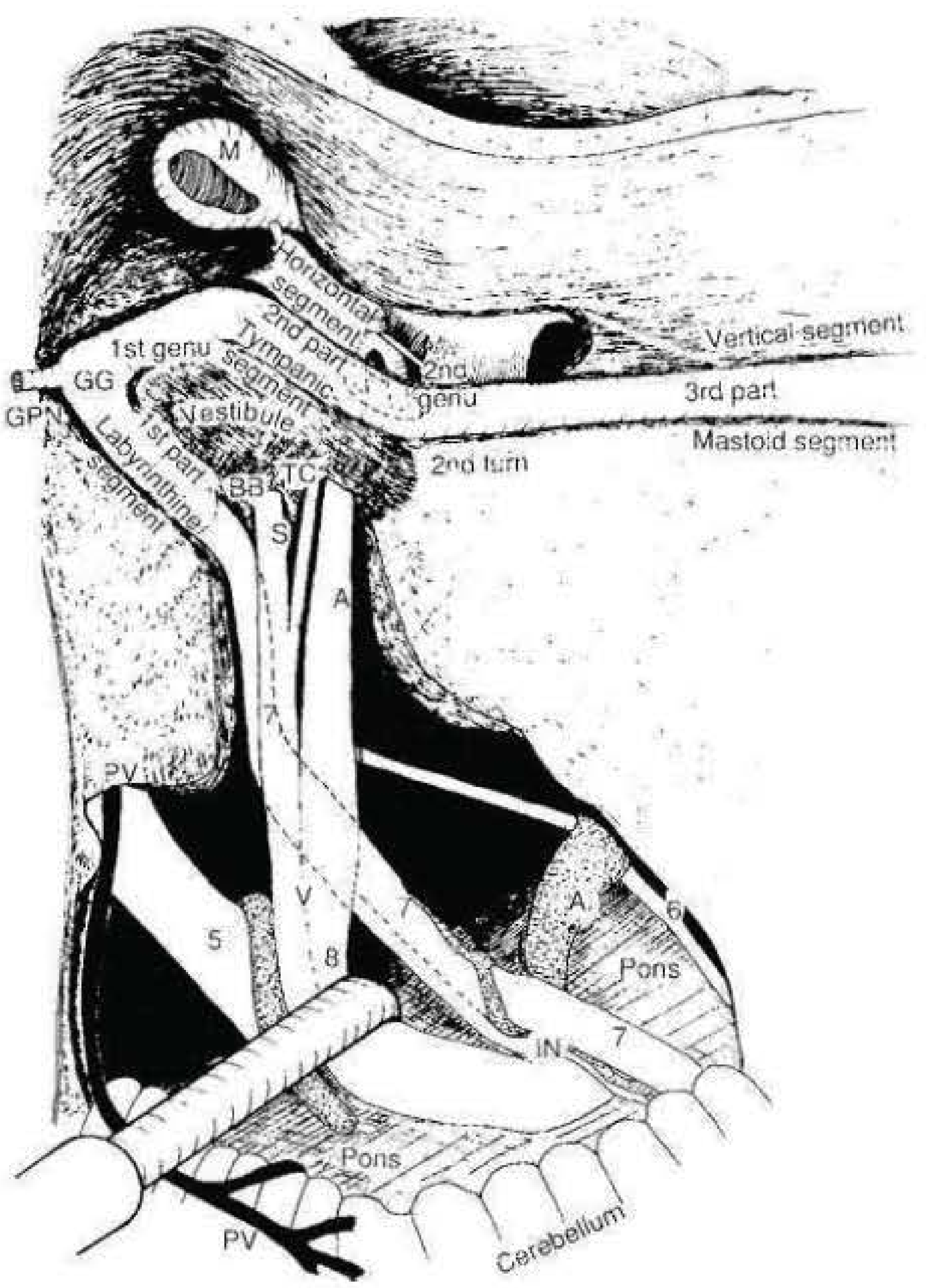


Fig. **107** **The entire course of the facial nerve** as seen in the translabyrinthine approach. The vestibule and internal auditory meatus are opened, as well as the posterior fossa dura, providing a good view into the cerebellopontine angle, cerebellum, and pons, and indicating the exits of the nerves. The facial nerve (7) and the acoustic nerve (8) are pulled in a superior direction to expose the facial nerve, the abducens nerve (6), and trigeminal nerve (5). The eighth nerve is separates toward the porus into the vestibular (V) and the acoustic nerve (A). The vestibular nerve separates into the superior vestibular nerve (S), exiting the internal acoustic meatus superior to the transverse crest (TC) and the inferior vestibular nerve (I), exiting inferiorly to the transverse crest. The labyrinthine segment of the facial nerve runs in the fallopian canal toward the geniculate ganglion (GG) at the first turn, and here the greater petrosal nerve (GPN) exits the ganglion. PV: petrosal vein; AI: anterior inferior cerebellar artery; IN: the intermedius nerve; BB: Bill's bar; M: head of the malleus

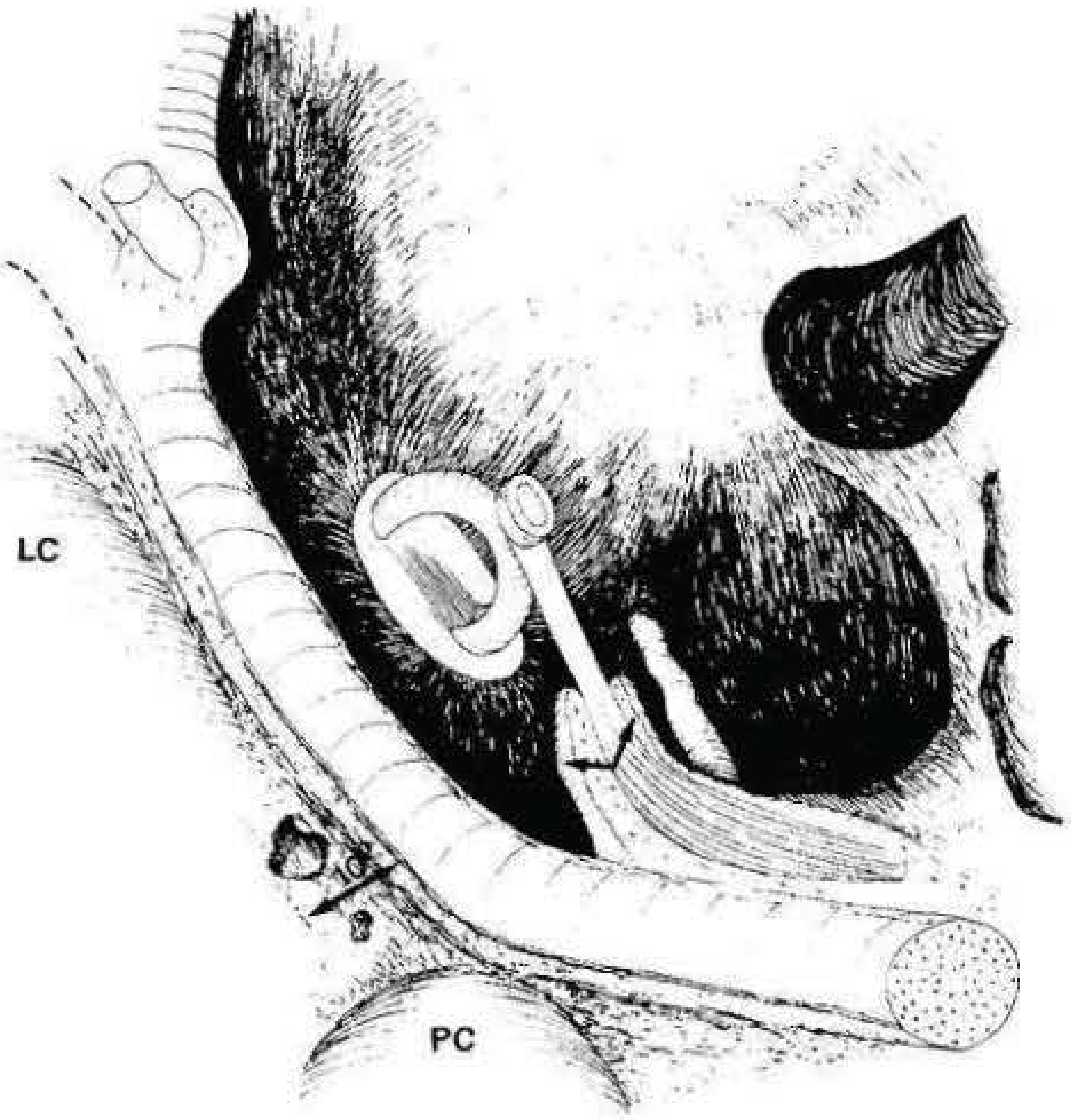


Fig. **108** **The horizontal part of the facial nerve**, with the second genu and the exposed stapedial muscle and its tendon. The dashed lines indicate the course of the facial nerve from the cochleariform process toward the genicular ganglion. The posterior tympanic sinus (arrows) extend both superior and inferior to the pyramidal eminence. The sinus tympani is located inferior to the ponticulus. The 10° angle between the course of the lateral semicircular canal (LC) and the horizontal part of the facial nerve is indicated. The posterior semicircular canal (PC) goes deep to the facial nerve

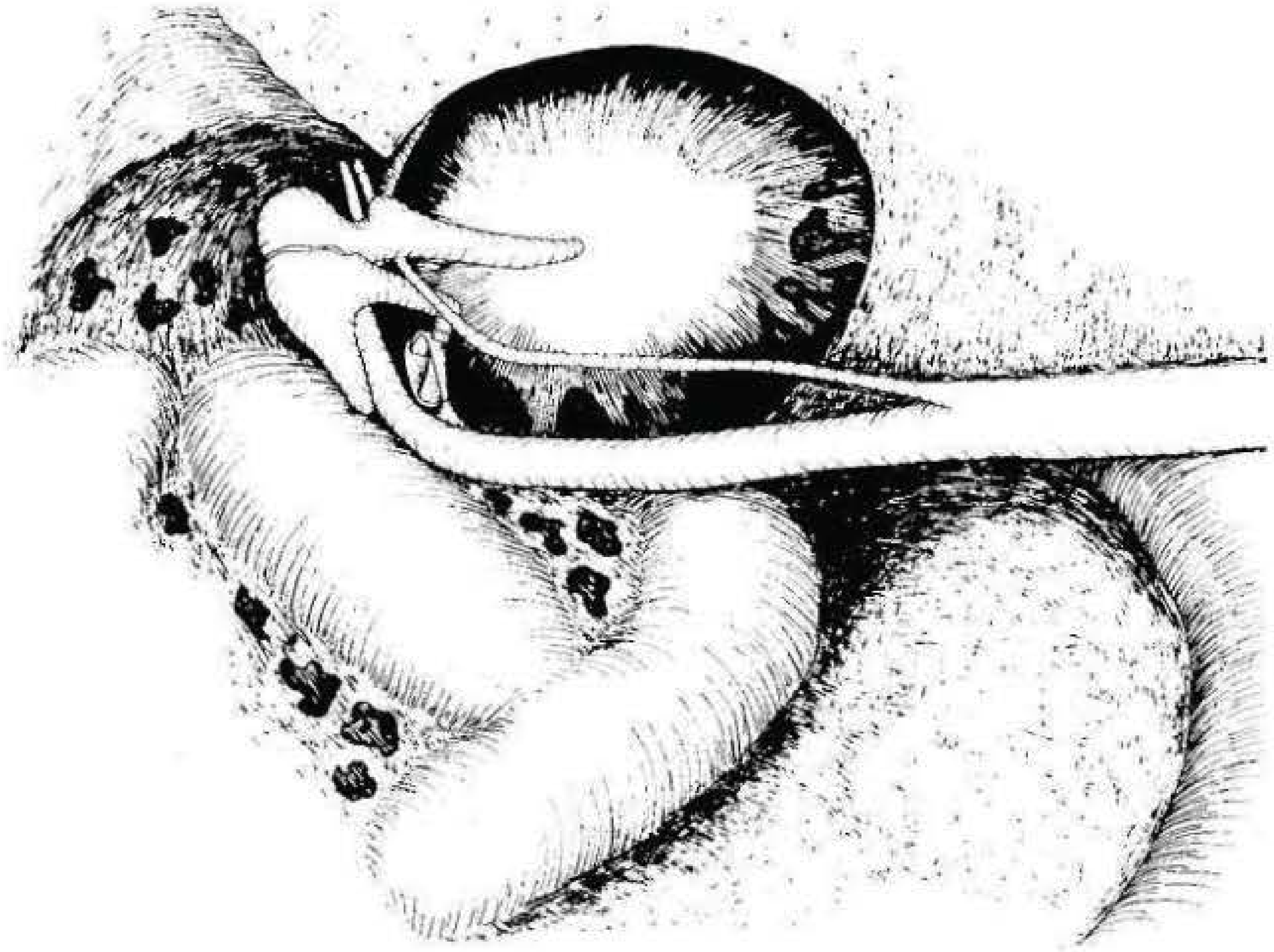


Fig. **109** **The exposed vertical segment of the facial nerve**, with the exit of the chorda tympani and the relationship of the facial nerve to the posterior semicircular canal. The sigmoid sinus runs medially to the facial nerve

3 The Pneumatic System of the Temporal Bone

The term pneumatization generally refers to the extent of air cells within the temporal bone and is in practice commonly used to classify the ears into extensively pneumatized, well pneumatized, fairly and poorly pneumatized ears, and finally non-pneumatized or sclerotic ears. The term pneumatization is also used in a pathogenetic context, and denotes the process of pneumatization that takes place from the perinatal period through to puberty and is genetically determined, though greatly influenced by the environment, since, for example, inflammatory middle ear diseases may occur during this period, especially during infancy and early childhood. Understanding pneumatization of the temporal bone is important for the middle ear surgeon for several reasons.

1. *Surgical-anatomical reasons.* It is important to know the variations of the air cell tracts, their location, extensions, and how they connect with each other.

The degree of pneumatization varies significantly and there are no two identical or even similar temporal bones, which is what makes mastoid surgery such a difficult task.The surgeon must know the extent of the air cells to be expected in the various regions of the temporal bone. The surgeon should also know when to stop the exenteration of air cells. Usually it is easy to follow and exenterate extensive mastoid air cells, but sometimes there is no end of them, and eventually the surgeon will create a huge cavity, with the problem of how to deal with it.

2. *The choice of surgical technique.* The degree of pneumatization of the temporal bone influences the surgeon in the choice of whether to perform canal wall–up or canal wall–down mastoidectomy.

Generally, it is technically easier and prognostically better to perform a canal wall–down mastoidectomy in ears with poor pneumatization than a canal wall–up mastoidectomy. In such ears, the space in the attic and antrum is limited, the dura is in a low position, and the mastoid process is constricted. Small cavities can easily be obliterated, or they can remain open. The chance of a small cavity remaining dry is better than with a larger cavity.

In ears with extensive pneumatization, a large cavity is usually the result when performing a canal wall–down mastoidectomy, and such a cavity is more difficult to obliterate than a small one. In addition, a large, open cavity is rarely dry and self-cleansing. In such cases, a canal wall–up mastoidectomy with an attempt at repneumatization may be the best solution.

Many surgeons and several schools of thought only entertain one solution—canal wall–up mastoidectomy technique for all cholesteatoma ears. Others suggest the opposite—a canal wall–down mastoidectomy technique for all cholesteatoma ears, irrespective of the degree of pneumatization. However, there are many additional arguments other than the degree of pneumatization for choosing canal wall–up or canal wall–down mastoidectomy; canal wall–up mastoidectomy is not the optimal procedure in all situations, nor is canal wall–down mastoidectomy. The choice of mastoidectomy technique has became more a question of the philosophy of the various surgeons concerned, than a rational consequence of research into the results of various techniques.

The present author believes that the optimal choice of mastoidectomy technique in each case of cholesteatoma lies somewhere between the two extreme views, and takes into consideration—amongst other things—the degree of pneumatization when deciding whether canal wall–up or canal wall–down mastoidectomy will be undertaken. In well-pneumatized ears, canal wall–up mastoidectomy is considered, and in poorly pneumatized ears, canal wall–down mastoidectomy is considered.

3. *Enlargement of the cavity.* Many schools and surgeons perform canal wall–up mastoidectomy and enlarge the mastoid cavity in order to improve the ventilation of the middle ear and thereby prevent postoperative retraction. They believe in the genetic or hereditary theory of pneumatization, claiming that a small air cell system is genetically determined and predisposes to chronic middle ear disease, or at least has a great influence on its course. It has been shown that cholesteatoma, adhesive otitis, secretory otitis and noncholesteatomatous otitis media are associated with hypocellularity, and this highly significant correlation is taken to support the hereditary theory (Diamant 1940, 1952). The supporters of the environmental theory (Wittmaack 1918, 1930, Tumarkin 1957, 1959, Palva and Palva

1966, Tos 1984) claim that the hypocellularity is a sequelae of middle ear diseases but not its cause.

The supporters of the genetic theory claim that a large cavity has a buffering effect on the changes in middle ear pressure caused by poor tubal functional, but they have not been able to demonstrate the mechanics involved in such a system. Several arguments suggest the opposite effect.

A. Children with a history of secretory otitis media at the age of four or five, but with normal hearing, ear drum, and tubal function at the age of 12, have not gone on to develop retraction for as long as they have been followed (until the age of 16), even if their mastoid air cell system was small (Tos and Stangerup, 1984; Tos et al. 1984 a, 1985).

B. Ears with otosclerosis that have undergone fenestration, eliminating the antrum and the mastoid process and converting them into an open cavity, have not developed retraction of the drum, even many years after surgery, indicating that the missing pneumatic system did not result in retraction of the normal drum.

C. The spontaneous or surgically created atticoantrotomy with exenteration of the antrum and mastoid cells does not necessarily lead to retraction of the pars tensa due to elimination of the mastoid process.

D. If one considers that negative middle ear pressure is a consequence of gas resorption from middle ear spaces, a large cavity with its large mucosal area should have a greater tendency to gas resorption, which can act in an opposite direction in cases with insufficient tubal function. This means that a large mastoid cavity could more easily contribute to negative pressure than a small cavity.

Hereditary and Environmental Pneumatization Theories

According to Diamant's hereditary or genetic theory, or "normal variant theory" (1940), the extent of pneumatization is genetically determined, and a small cellular system predisposes to chronic or acute otitis media.

According to Wittmaack's endodermal theory (1918), normal middle ear mucosa is a prerequisite for the normal pneumatization process, which is therefore hampered by inflammation or tubal dysfunction. Middle ear diseases in infancy and early childhood are thus the *cause* of the reduced pneumatization. This theory is also called the environmental theory by "neo-Wittmaackians" (Tumarkin 1957, 1959, Gans and Wlodyka 1966, Palva and Palva 1966, Tos 1982b). Wittmaack based his theory on extensive histopathological studies in human temporal bones.

In sharp contrast to Wittmaack's theory, Diamant's theory proposes that otitis media is a *result* of reduced pneumatization. Diamant (1940) performed extensive planimetric measurements on radiographs from 320 consecutive patients hospitalized for scarlet fever. The criterion for normality was no acute otitis media in connection with scarlet fever, and no chronic otitis media with perforation. Excluded from the study were only eleven patients who had earlier undergone mastoidectomy. Included were those patients who had earlier, especially in childhood, suffered acute otitis media, chronic tubal dysfunction, or chronic secretory otitis media. Diamant found the average size of the cellular system to be 12 cm^2 and the distribution within the material regarding the size of the cellular system to have an almost Gaussian shape (Fig. **110**). This Gaussian distribution of a normal population is the cornerstone of the genetic theory, and the considerable individual variation that is seen, as well as left-right variations, are supposed to result from genotypic asymmetry.

Our own epidemiological studies (Tos 1982 b, Tos and Stangerup 1984; Tos et al. 1984 b) on healthy children strongly contradict the genetic theory. We have performed repeated tympanometric screening on three cohorts of otherwise healthy children. In the first cohort, comprising 90 infants born consecutively at our hospital, the first tympanometry was performed at the age of two days, and the following four at ages of three, six, nine, and 12 month. During the first year of life, 14% of the ears already had

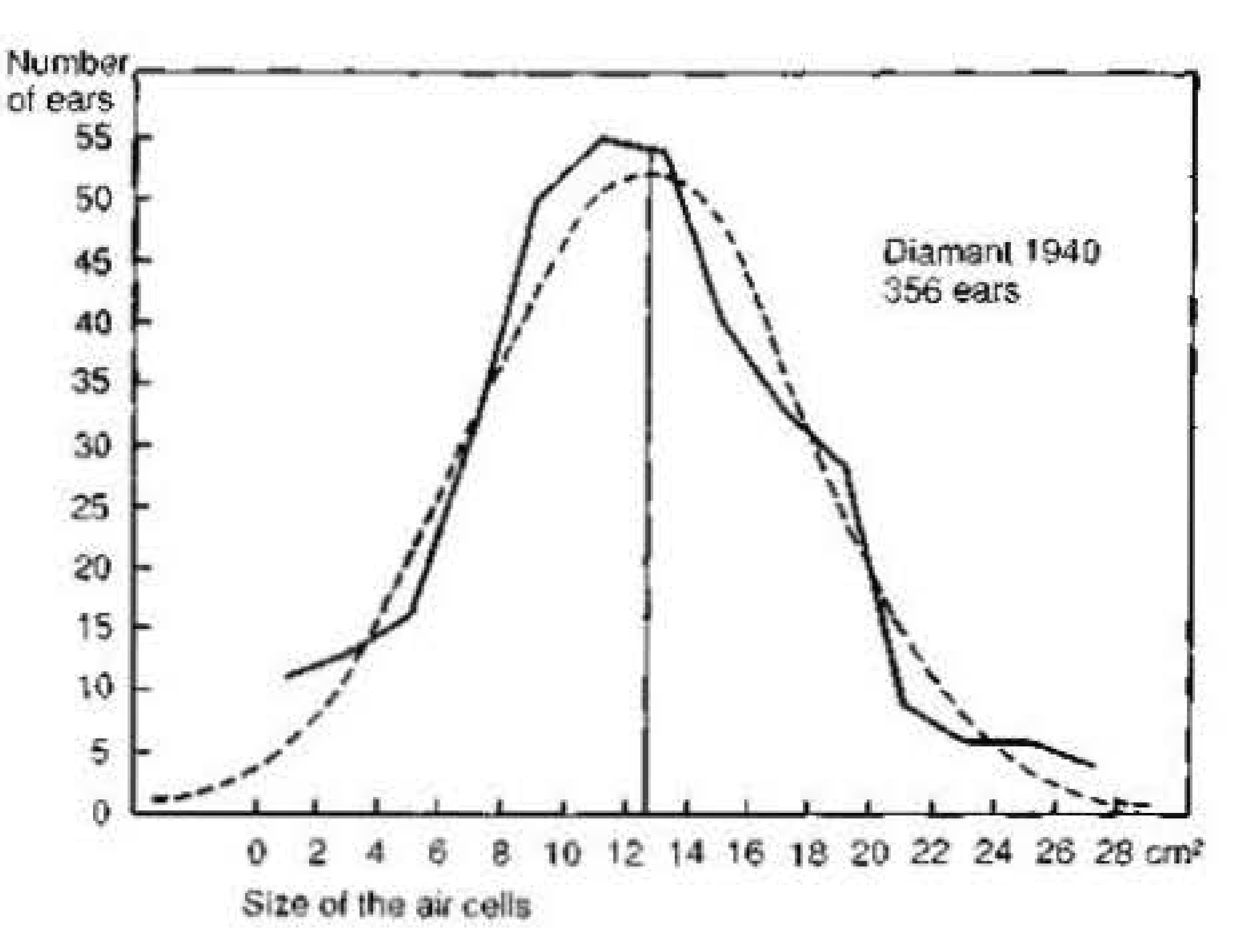


Fig. **110** **The size of the mastoid air cell system** found by Diamant (1940) in consecutive patients hospitalized for scarlet fever. The dashed line indicates the Gaussian curve. After Diamant (1940)

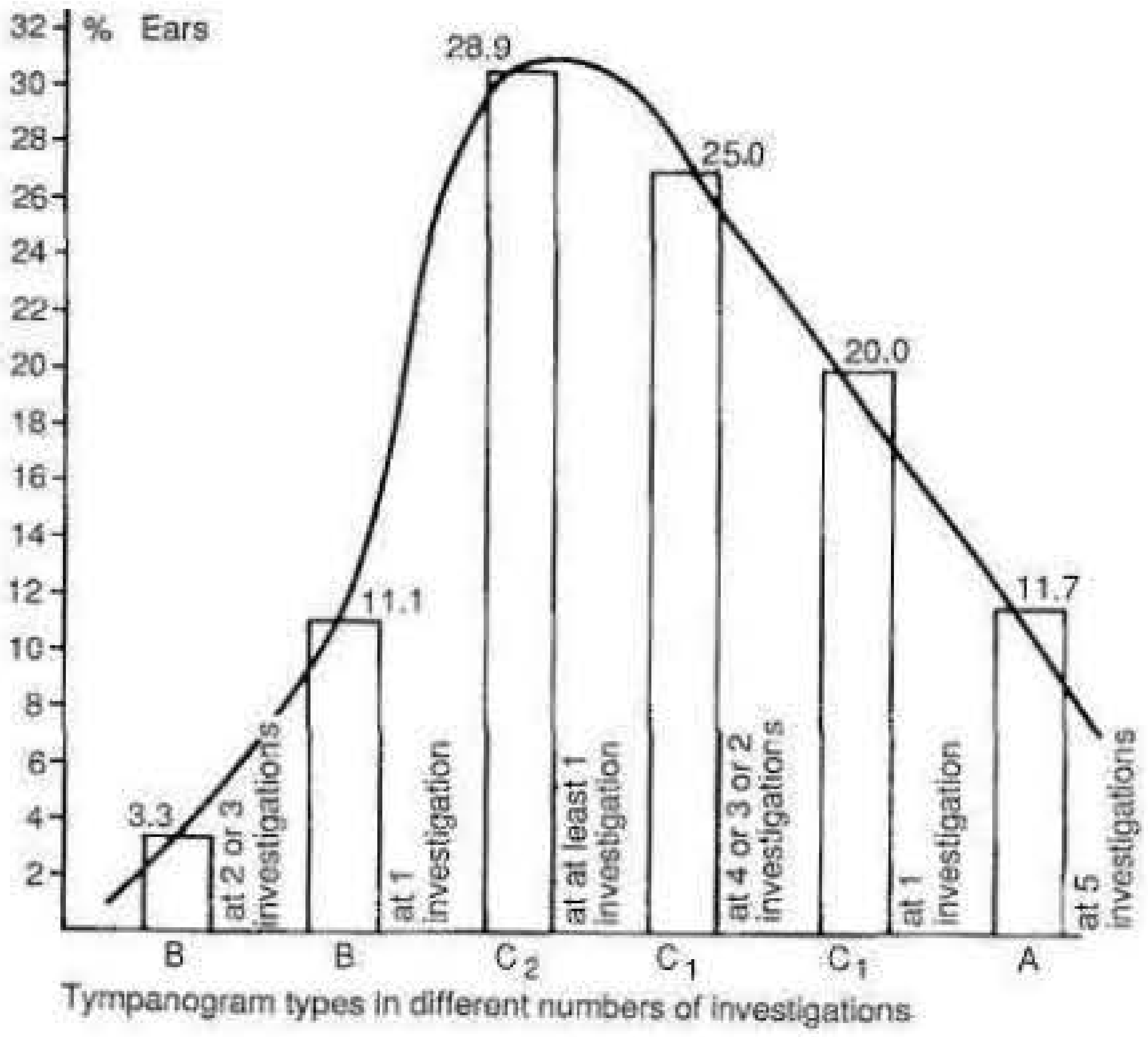


Fig. **111** The Gaussian distribution of the severity and duration of middle ear and tubal diseases expressed in five tympanograms obtained during the first year of life in 90 otherwise healthy infants (180 ears). The most severe, ears are on the left side of the curve, and the completely healthy ears are on the right (Tos, Acta Otolaryngol, 1982 b)

secretory otitis media, and another 30% had tubal dysfunction. The distribution of the degree of severity and duration of tubal dysfunction or mucosal pathology, or both, in normal children forms a Gaussian curve (Fig. **111**), with severe and protracted cases at one end of the spectrum and ears that apparently have never been exposed to a pathological state at the other end.

In our second cohort, consisting of 184 otherwise healthy two-year-old children followed up over 27 months by six tympanometries, a Gaussian curve of severity of disease was also found (Fig. **112**).

In our third cohort consisting of 288 four-year-old children investigated by five tympanometries every three months for one year, 73% had type B or type C_2 tympanograms at least once. The severity of tubal dysfunction and secretory otitis media again had an almost Gaussian distribution (Fig. **113**).

By performing quantitative histology on autopsy material for children over two years whose middle ears were clinically normal, we found mucous glands in the middle ear mucosa in 90% of the ears (Bak-Pedersen and Tos 1973). The mucous glands were definitely pathological, and were formed due to previous disease, either secretory otitis or acute otitis media. Normally there are no glands in the middle ear mucosa. The distribution of the total number of glands was again Gaussian (Fig. **114**).

At autopsies from clinically normal temporal bones from adults, mucous glands were found in 91 % of the middle ears. As regards the total number of glands, the material showed an almost Gaussian distribution (Fig. **115**). The glands found in adults

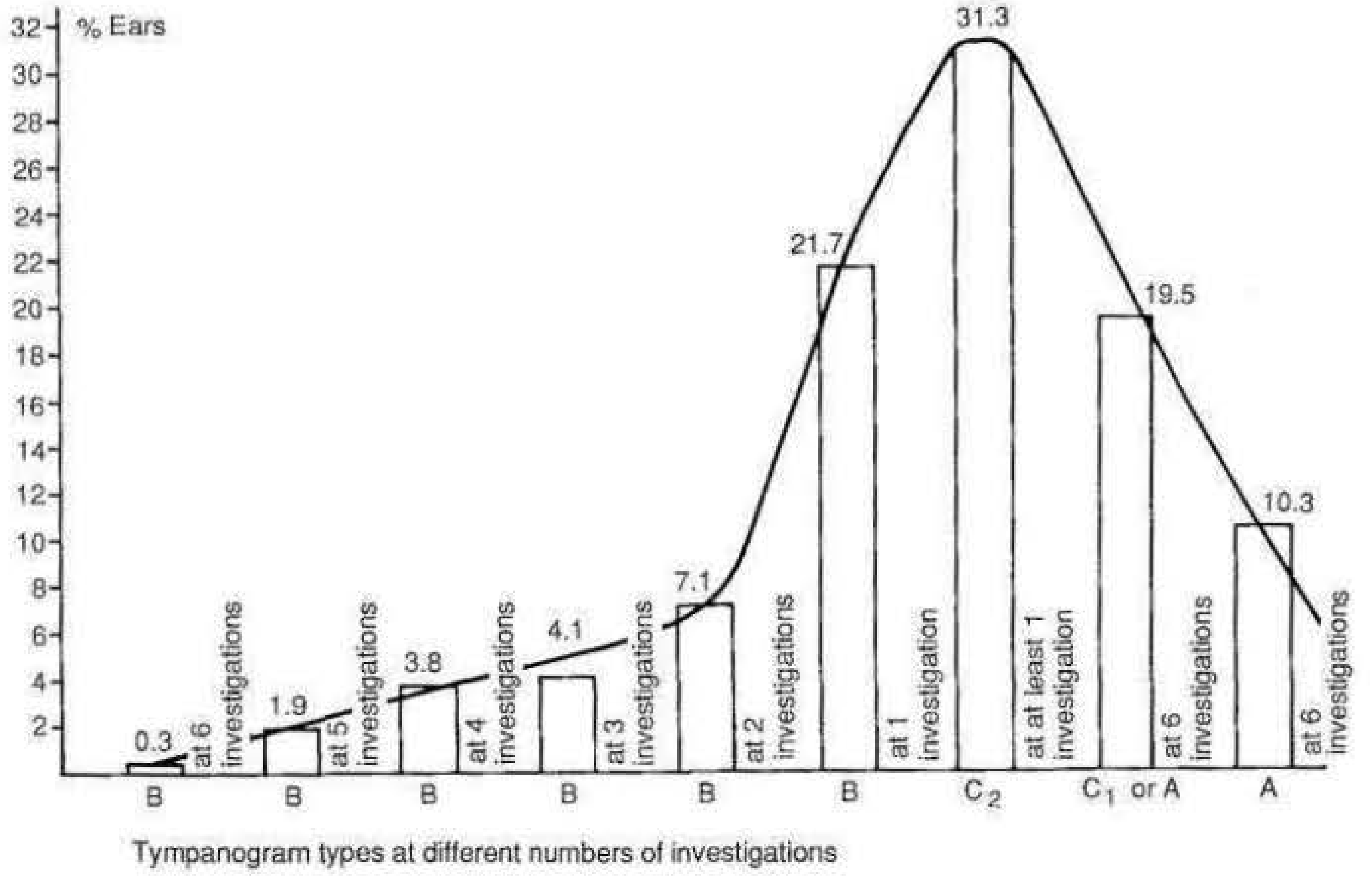


Fig. **112** The Gaussian distribution of the percentage of 368 ears with different combinations of severity and duration of middle ear diseases in 184 2-year-old children followed with six tympanometries during a 27-month period (four tympanometries every three months, the fifth six months later, and the sixth 12 months later) (Tos 1982 b)

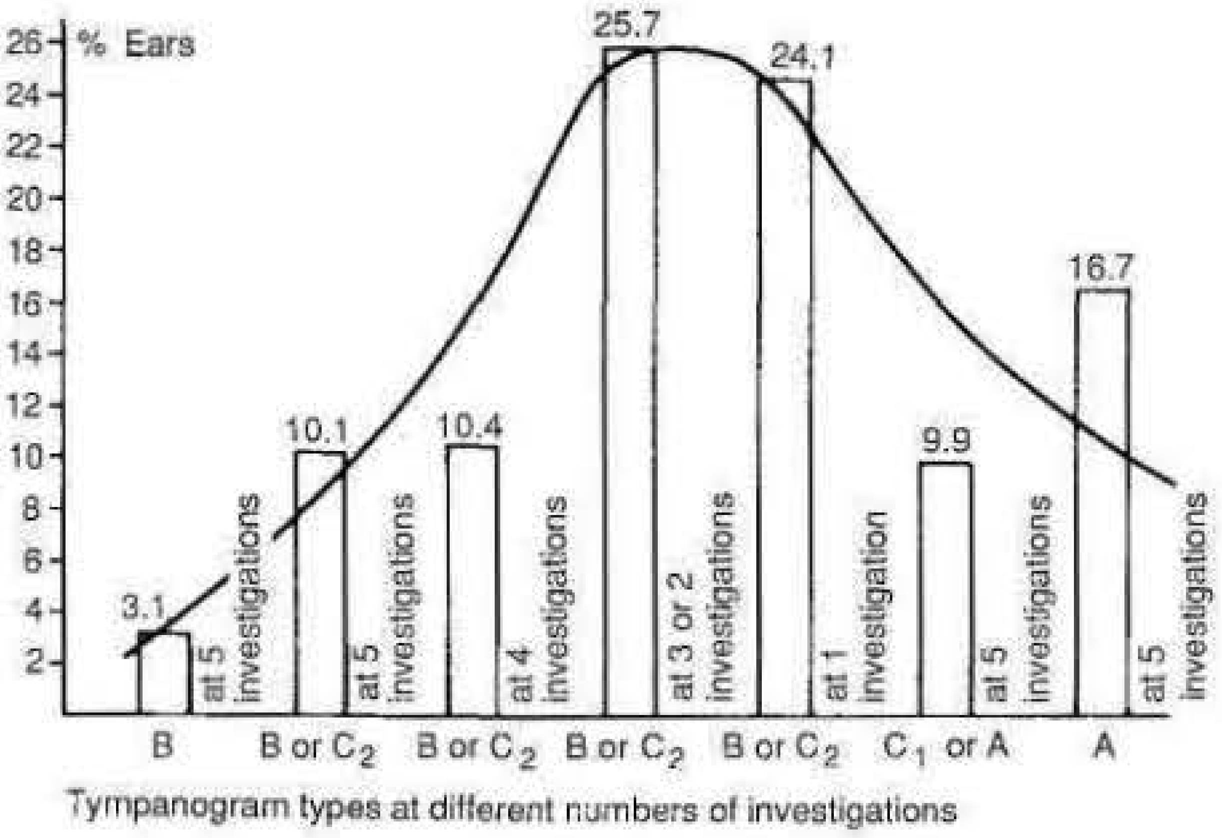
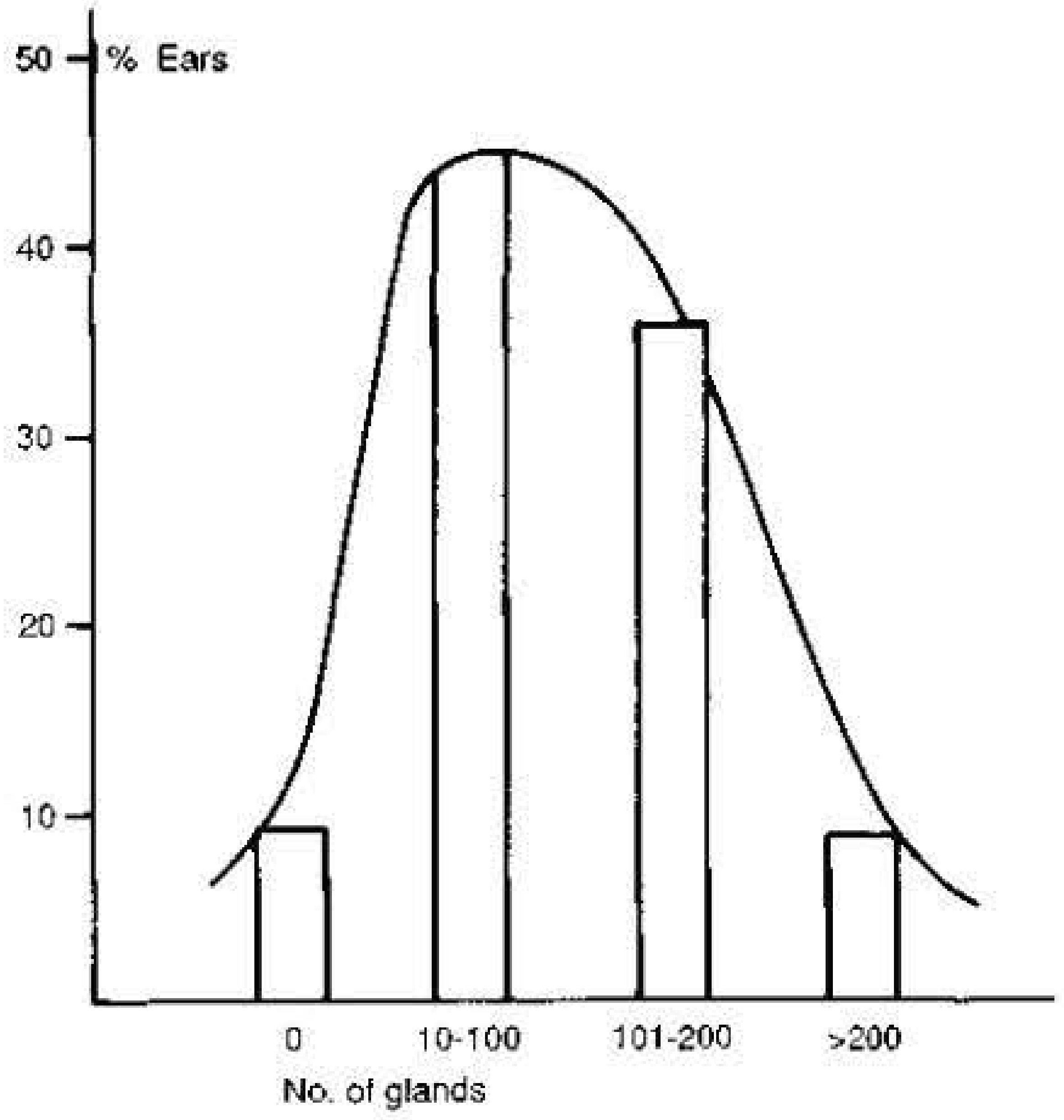


Fig. **113** A similar Gaussian curve to those in Figures **111** and **112**, but based on five repeated tympanometries every three months in a different study group consisting of 288 4-year-old children (576 ears) (Tos 1982 b)

are thought to be sequelae of pathological changes of the mucosa in childhood (Bak-Pedersen and Tos 1973).

These studies have shown that the middle ear mucosa in childhood, when the pneumatization process is taking place, is exposed to pathological stimuli of various degrees of severity and duration. These stimuli may have a considerable effect on the process of pneumatization, the end results of which may be large variation in the size of the cellular system.

It is well known that the process of pneumatization takes place from birth throughout childhood. It is also well known and documented by several human histological and experimental studies (Sadé 1979, Tos 1980 a) that the mucosa is severely pathologically altered in secretory otitis media and in acute suppurative otitis media. It was shown by Wittmaack (1918) that pathological changes in the mucosa hamper the developing process of pneumatization, and the variation in the size of the cellular system can be fully explained by the range of exposure to disease. The Gaussian distribution of the variations in size of the air cells, which is the cornerstone of the hereditary theory can thus—with better evidence—be taken as the cornerstone of the environmental theory. Diamant's so-called "normal" population of children and adults were—as in our materials—exposed to upper respiratory tract infections during early childhood, resulting in secretory otitis media and acute otitis media that influenced the process of pneumatization and resulted in the variation of the air cell system.



△

Fig. **114** The total number of abnormal mucous glands found in the middle ear mucosae of 11 temporal bones from children with clinically normal middle ears (Tos 1982 b)

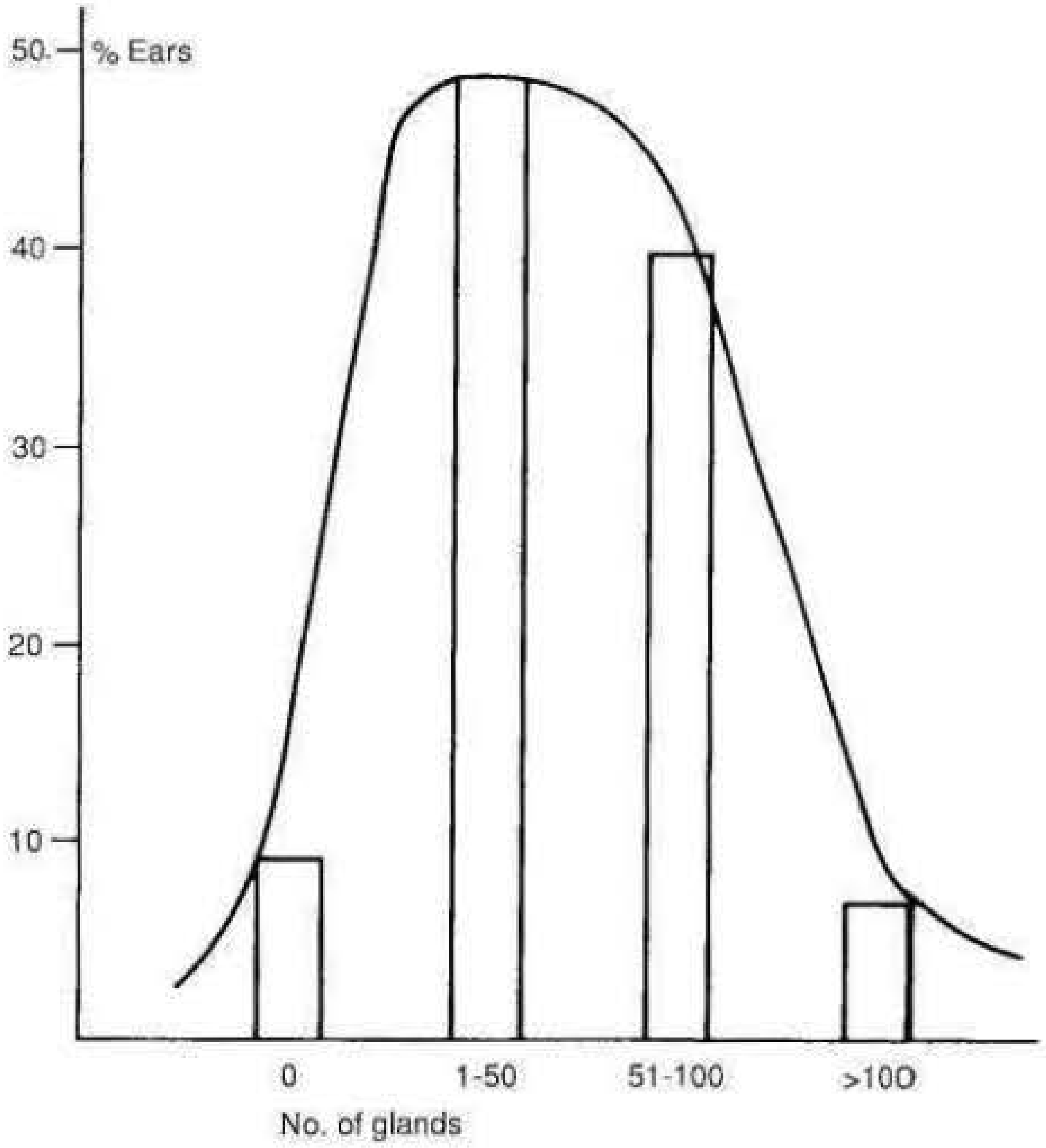


Fig. **115** The total number of abnormal mucous glands found in the middle ear mucosae of 45 clinically normal middle ears in adults (Tos 1982 b)

The Size of Air Cells and Previous Disease

Our epidemiological studies provide definitive proof that the variation in size of the air cells system is a direct consequence of previous disease.

The three cohorts of otherwise healthy children (Figs. **111–113**) followed up by several repeated tympanometries and otomicroscopies have also been examined radiologically, and the size of the air cell system was measured planimetrically and blindly estimated. Forty-one children from the first cohort (Tos et al. 1984 a) were radiologically examined at the age of six, after 13 tympanometries (Fig. **111**), as were 79 children from the second cohort (Tos et al. 1985) at the age of seven, after nine tympanometries (Fig. **112**), and 41 children from the third cohort (Tos and Stangerup 1984) at the age of eight, after seven tympanometries (Fig. **113**). At the time of evaluation, the middle ears of all the children were clinically healthy, but children with a history of previous secretory otitis media of a severe or extended duration had significantly smaller air cell systems than children with a history of limited disease (Table **2**). Significantly, the largest air cell systems were found in children with no previous disease.

It has also been demonstrated that individual asymmetry in the size of the cell system can be attributed to a history of more extensive previous middle ear pathology on the side of the smaller cell system (Tos and Stangerup 1985 a). It has also been shown that the reason why boys have smaller air cell systems is that they generally have more middle ear disease during infancy than girls (Tos and Stangerup 1985 b). It has also been shown that the insertion of grommets has a positive effect on the process of pneumatization (Stangerup and Tos 1986).

Table **2** Degree of pneumatization in ears from all three cohorts, pooled together and divided into four severity groups

Degree of pneumatization	Tympanogram types			
	B twice or more	B once	C_2 twice or more	C_2 never or once
	n=76	n=48	n=57	n=106
1 Very small	30	2	4	1
2 Small	32	29	12	13
3 Moderate	22	29	46	27
4 Large	12	25	32	42
5 Very large	4	15	7	17
Rank sum test	$p<0.01$	n. s.	$p < 0.01$	

The Pneumatization Process

The normal process of pneumatization starts in the perinatal period in the last weeks before birth, and progresses during infancy and childhood through to puberty, when the last part of the petrous apex is pneumatized.

Embryonic mesenchyme, which in the eighth fetal month is found in the upper two-thirds of the tympanic cavity, is gradually reduced. At birth, the entire tympanic cavity is filled with air, with the antrum still partly filled with mesenchyme.

The pneumatization of the mastoid process starts at birth with the development of the periantral cells, and continues through early childhood toward the mastoid tip. From the antrum, pneumatization continues toward the labyrinth and the apex of the pyramid (Wittmaack 1918, Rainer 1938). At puberty, the last part of the petrous bone is pneumatized. Air cells of the mastoid process start to develop from the antrum, but some peritubal and hypotympanic cells develop from the Eustachian tube and the hypotympanum, respectively. Some air cell tracts originating in the hypotympanum continue toward the mastoid process, passing medially to the vertical portion of the facial nerve.

The pneumatization process of the air cells can be divided schematically into three stages: 1) Lacunar resorption of the bony trabeculations of the spongiotic bone by the mesenchymal tissue. In the lacunas, extensive osteoclastic activity is found. 2) Invasion of fibrous tissue into the lacunar spaces and displacement of the bone marrow. 3) Disappearance of the fibrous tissue and ingrowth of epithelium into the air cells. Further lacunar resorption of the bone takes place at the base of the cells, and formation of new air cells starts again in the same manner. This process continues as long as there is spongiotic marrow in the temporal bone. The normal process of pneumatization requires normal middle ear mucosa, and is disturbed and delayed by any pathological process in the middle ear, such as infection or inflammation.

The Air Cell Tracts

The air cell system of the temporal bone can be divided into:

1. *Mastoid air cell tracts,* which are the result of the mastoid pneumatization, originating in the antrum.
2. *Petrous bone cell tracts,* divided into a) *perilaby-*

rinthine cell tracts, which are the result of petrous bone pneumatization starting in the antrum, and b) *petrous apex cell tracts,* originating in the antrum, hypotympanum, and Eustachian tube.

3. *Sublabyrinthine cell tracts,* originating from the Eustachian tube and hypotympanum.
4. *Precochlear or inferior prelabyrinthine cell tracts,* originating from the antrum, Eustachian tube, and hypotympanum.

Mastoid Air Cells

Since the antrum is the site of origin of the mastoid air cells, the first to develop are the periantral and tegmental cells, as well as the central mastoid cells.

In adults, several mastoid air cell systems can be distinguished. They can be divided and subdivided in various ways, and the classification described by Allam (1969) and slightly modified by the present author will be used here (Fig. **116**).

1. The *periantral cells* surround the antrum on all sides and occupy the anterosuperior portion of the mastoid process (Fig. **116**).

2. The *tegmental cells* extend along the middle fossa dura plate. They can be subdivided into mastoidal tegmental cells, antral tegmental cells, and tympanic tegmental cells, relating to the classification of the three subdivisions of the tegments stressed by the author. The periantral cells are in fact antral tegmental cells (Fig. **116**).

3. The *sinodural cells* occupy the sinus dura angle and are bounded superiorly by the middle fossa dural plate, and inferiorly by the dural plate over the superior part of the sigmoid sinus (Fig. **116**).

4. The *perisinusal cells* lie around the sigmoid sinus. They can be subdivided into *posterior perisinusal cells,* lying posterior to the sigmoid sinus, *lateral perisinusal cells,* lying lateral to the sinus, and *medial perisinusal cells,* lying medial and anterior to the sinus. Because the posterior perisinusal cells (or retrosigmoid cells) can reach far posteriorly into the occipital bone in extensively pneumatized ears, the present author has further subdivided them into the *superior* and *inferior retrosigmoidal cells* (Fig. **116**).

5. The *central mastoid cells* occupy the central area, which extends from the antrum down to the mastoid tip. These cells are usually large cells (Fig. **116**). They can be further subdivided into *superficial* and *deep intersinofacial cells.*

6. The *mastoid tip cells* or *apical cells,* which again are usually large cells, are subdivided into *lateral apical cells,* lying lateral to the digastric crest, and *medial apical cells,* lying medial to the digastric crest and inferior to the sigmoid sinus (Fig. **116**).

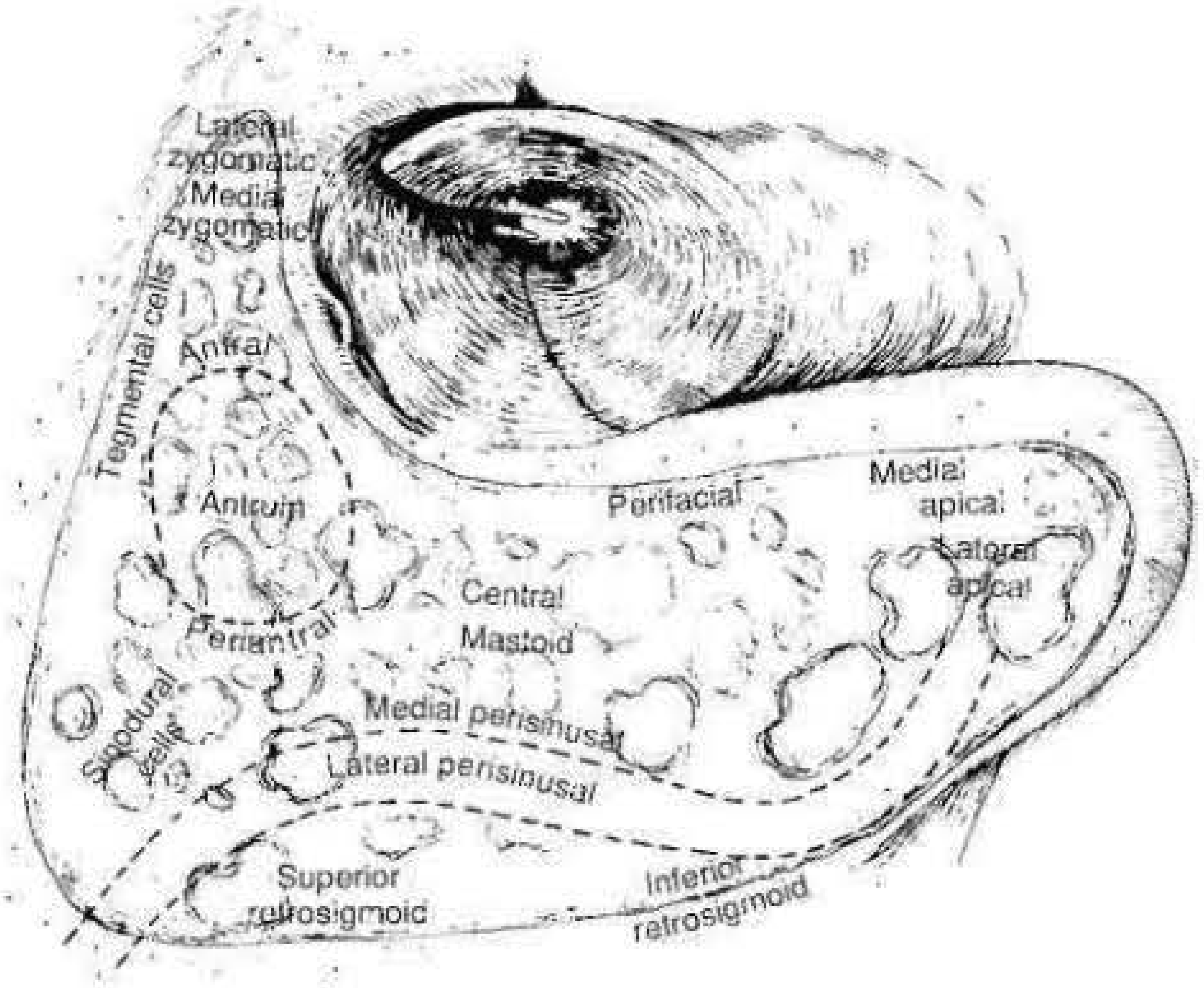


Fig. **116** **The air cells of the mastoid process**. Posteriorly around the sigmoid sinus lie the medial and lateral perisinusal cells, and behind the sinus the superior and inferior retrosigmoidal cells. In the mastoid apex lie the lateral and medial apical cells. Around the facial nerve are the perifacial cells. Around the antrum are the periantral cells, and toward the aditus ad antrum lie the antral cells. The tegmental cells are located along the middle fossa dura plate. Anteriorly, the lateral and medial zygomatic cells are seen.

7. The *perifacial cells* lie adjacent to the posterior and lateral aspects of the vertical segment of the facial nerve (Fig. **116**). The cells of the facial recess are also perifacial cells. The perifacial cells connect with the tympanic cavity above the fossa incudis, not through the facial recess.

8. The *zygomatic cells* are divided into the *lateral* and *medial zygomatic cells.* They occupy the most anterior space between the posterosuperior part of the external auditory meatus and the middle fossa dural plate. They can extend anteriorly far into the zygomatic arch (Fig. **116**).

9. The cells lying around the superior and lateral walls of the aditus ad antrum and the epitympanum are termed the *antral cells* (Fig. **116**).

In ears with extensive pneumatization, the air cells are large and extend posteriorly around the sigmoid sinus. In ears with limited pneumatization, the perisinusal cells are not present, but antral cells, periantral cells, and tegmental cells are usually present.

Perilabyrinthine Cells

The air cells of the perilabyrinthine region are further subdivided into 1) supralabyrinthine or superior perilabyrinthine cell tracts, and 2) sublabyrinthine or infralabyrinthine cell tracts. The border between these two areas is the vestibular aqueduct.

Superior Perilabyrinthine Cell Tracts

The superior perilabyrinthine cell tracts extend around the labyrinth anteriorly from the superior surface of the cochlea to the vestibular aqueduct posteriorly (Fig. **117**). They may continue superior to the labyrinth by one of four possible superior routes towards the apex of the pyramid, but they may stop as a cul-de-sac before reaching the apex. The superior perilabyrinthine cells tracts are:

1. *Superior prelabyrinthine cell tract.* These cells originate from the medial wall of the aditus ad antrum, and enter the triangular prelabyrinthine zone superior to the ampullae of the lateral and superior semicircular canals (Fig. **117**), but inferior to the geniculate ganglion and the Fallopian canal. The cells extend medially, passing the superior semicircular canal and then to the supralabyrinthine cells located superior to the internal auditory canal—the superior perimeatal cells (Fig. **118**).

2. *Translabyrinthine or intralabyrinthine cells.* These cells originate from the antrum and occupy the "triangle" formed by all three canals (Fig. **117**). They pass as a *suharcuate cell tract* with the subarcuate artery through the labyrinth to the medial side of the superior semicircular canal, before reaching the supralabyrinthine and the suprameatal cells above the internal auditory meatus (Fig. **118**). These

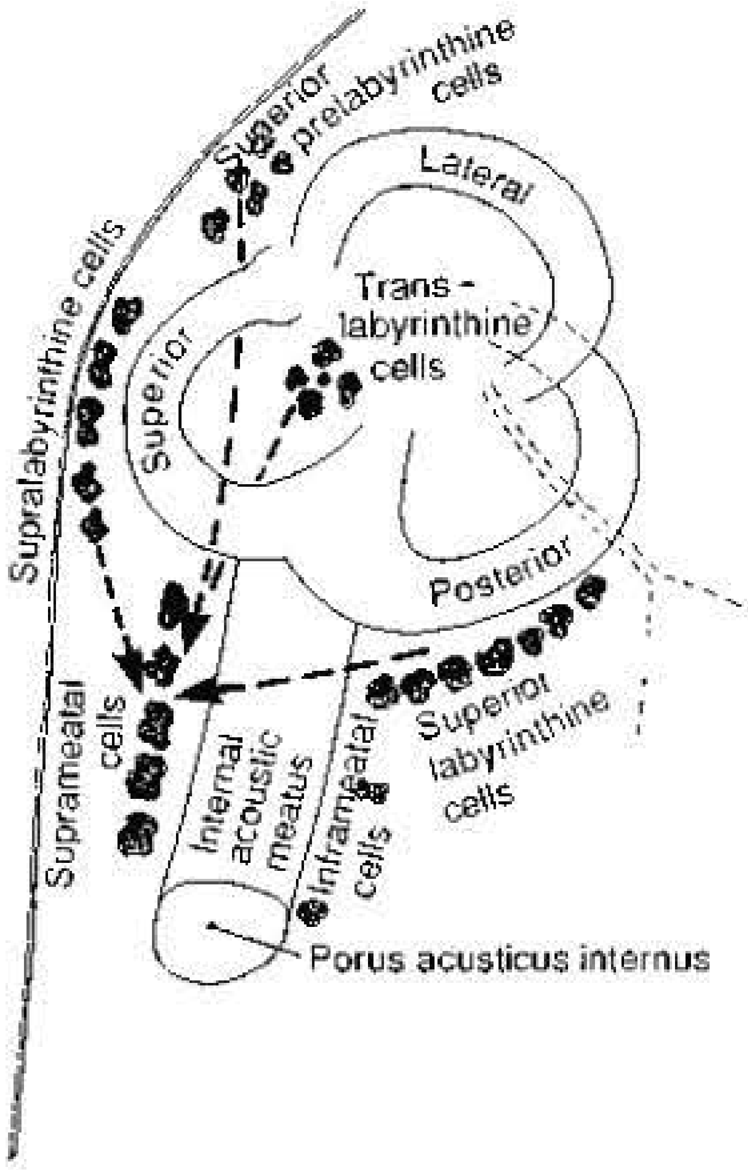

Superior prelabyrinthine cells
Lateral
Trans-labyrinthine cells
Superior
Supralabyrinthine cells
Posterior
Superior labyrinthine cells
Suprameatal cells
Internal acoustic meatus
Inframeatal cells
Porus acusticus internus

Fig. **118** **The connections between the perilabyrinthine cell tracts and the petrous apex**; the suprameatal and inframeatal cells. The superior prelabyrinthine cells and translabyrinthine cells sometimes communicate with the suprameatal cells. The supralabyrinthine and retrolabyrinthine cells quite often communicate with the suprameatal cells

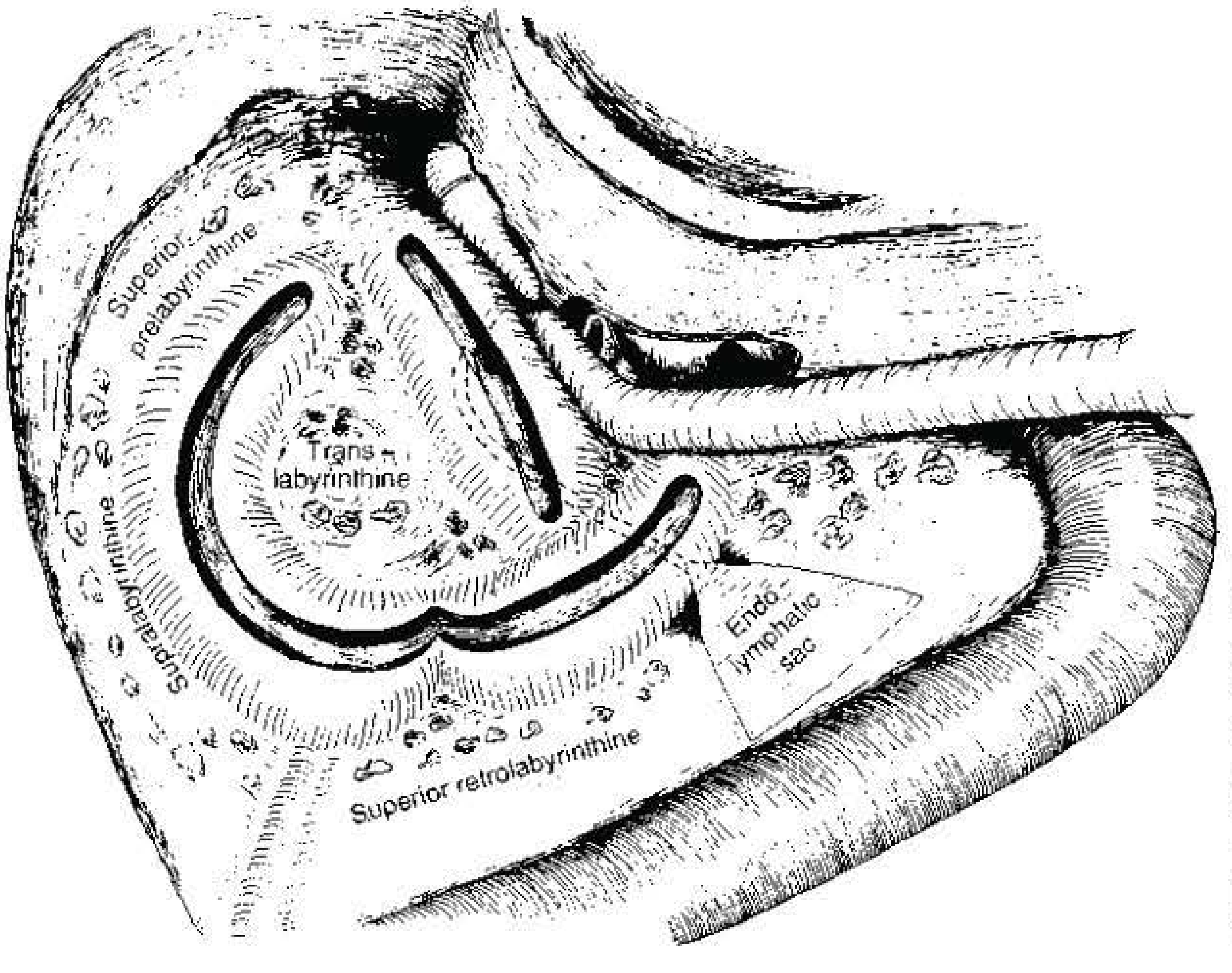

Superior prelabyrinthine
Trans-labyrinthine
Supralabyrinthine
Endolymphatic sac
Superior retrolabyrinthine

Fig. **117** **The perilabyrinthine air cells.** Posteriorly, the sigmoid sinus is skeletonized. The posterior fossa dura and the endolymphatic sac are exposed. Around the labyrinth, the prelabyrinthine, supralabyrinthine, and retrolabyrinthine cells are seen. The translabyrinthine cells lie between the three semicircular canals, which have been opened cells are only seen to penetrate through the entire temporal bone in 2–3% of cases (Proctor 1989) but on the antral side, the intralabyrinthine cells are frequently seen between the semicircular canals.

3. *Supralabyrinthine cells or petrosal crest cells.* These cells are a prolongation of the periantral cells which extend along the middle fossa dural plate superior to the superior semicircular canal and superior to the junction of the superior and posterior canals (Fig. **117**). They end superior to the internal auditory meatus as suprameatal cells (Fig. **118**).

4. *Superior retrolabyrinthine or retrolabyrinthine cells.* These cells extend from the periantral cells posterior to the posterior semicircular canal, and occupy the space between the posterior fossa dural plate and the posterior semicircular canal. They are located superior to the vestibular aqueduct (Fig. **117**). They pass around the posterior aspect of the common crus to reach the confluence of the superior perilabyrinthine cells above the internal auditory meatus as suprameatal cells (Fig. **118**). Although the superior retrolabyrinthine cell tract occupies the space between the posterior fossa dural plate and the posterior semicircular canal, it has never been seen to pass inferior to the internal auditory canal to reach the apex by the shortest route. These cell tracts always ascend toward the middle fossa dural plate, and pass to the apex superior to the internal auditory canal (Proctor 1989).

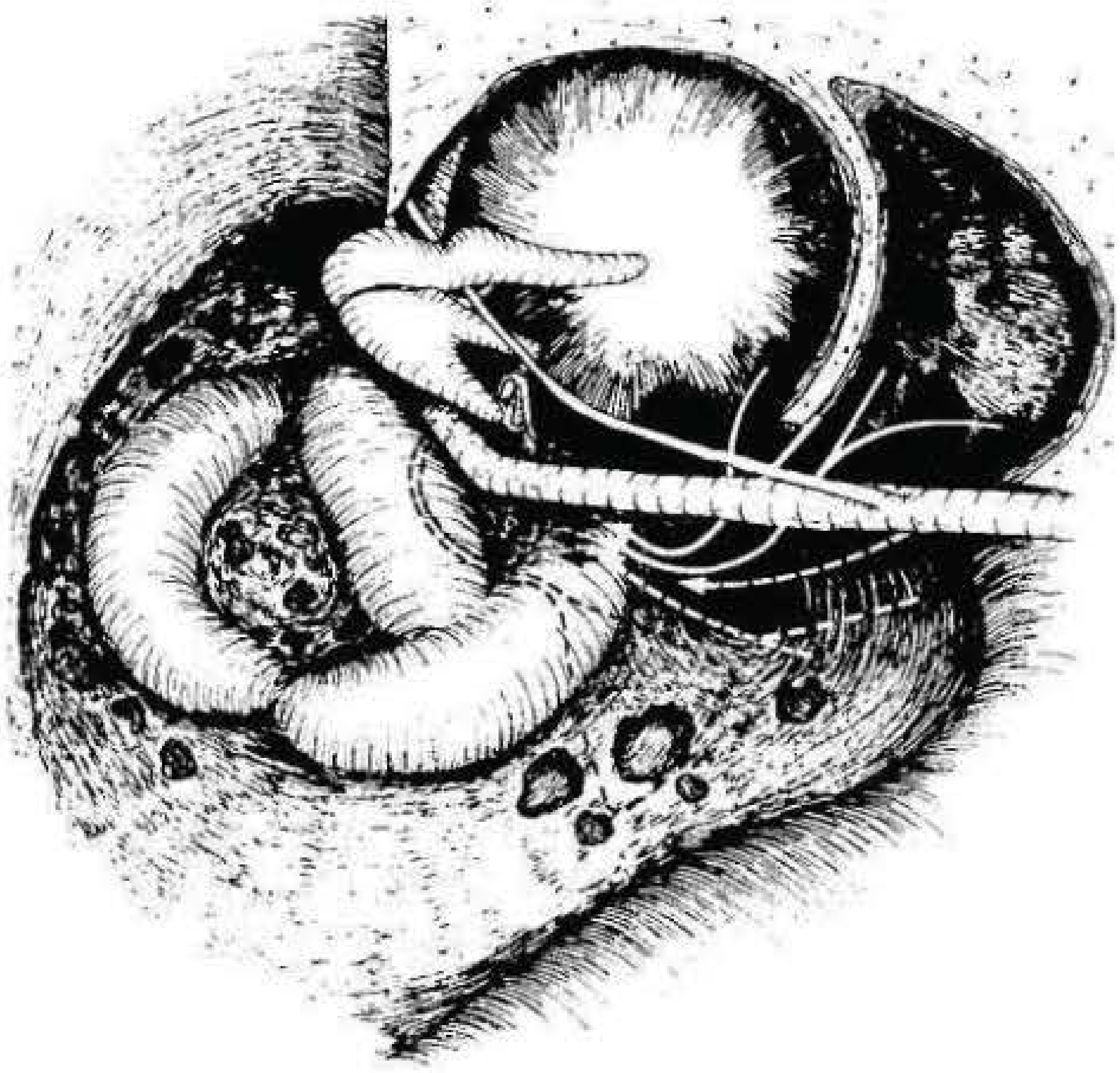


Fig. **119** **The connections between the sublabyrinthine and the apical cells**. The sublabyrinthine cells, originating from the hypotympanum, continue medial to the facial nerve and under the labyrinth toward the inframeatal cells and the apical cells (arrows). The infralabyrinthine air cells, the deep intersinofacial cells, continue to the petrous apex joining the sublabyrinthine cells (dashed arrows). The posterior part of the tympanic ring has been removed, and the facial nerve is exposed

Sublabyrinthine Cell Tracts

These cell tracts originate from the hypotympanum. They occupy the space inferior to the cochlea, between the carotid canal and the dome of the jugular bulb (Fig. **119**). They pass posteromedially, medial to the facial nerve, and open into the region inferior to the internal auditory meatus, continuing as the inframeatal cells to the petrous apex.

In about 70% of temporal bones, the dome of the jugular bulb is more or less high in its position and occupies the sublabyrinthine space, barring the route to the apex for cells that lie behind the mastoid portion of the facial nerve canal.

If the jugular dome is absent or relatively low in its position (approximately 30%), there is a large space for the sublabyrinthine cells, originating from the hypotympanum, and for the infralabyrinthine cells, originating from the perifacial cells and retrofacial cells, as well as from the intersinofacial cells and the cells from the occipital and jugular regions (Figs. **119, 120**). These cells fuse under the labyrinth and pass towards the petrous apex, gliding along the inferior wall of the labyrinth under the cochlear aqueduct to lie inferior to the internal auditory meatus (Fig. **121**).

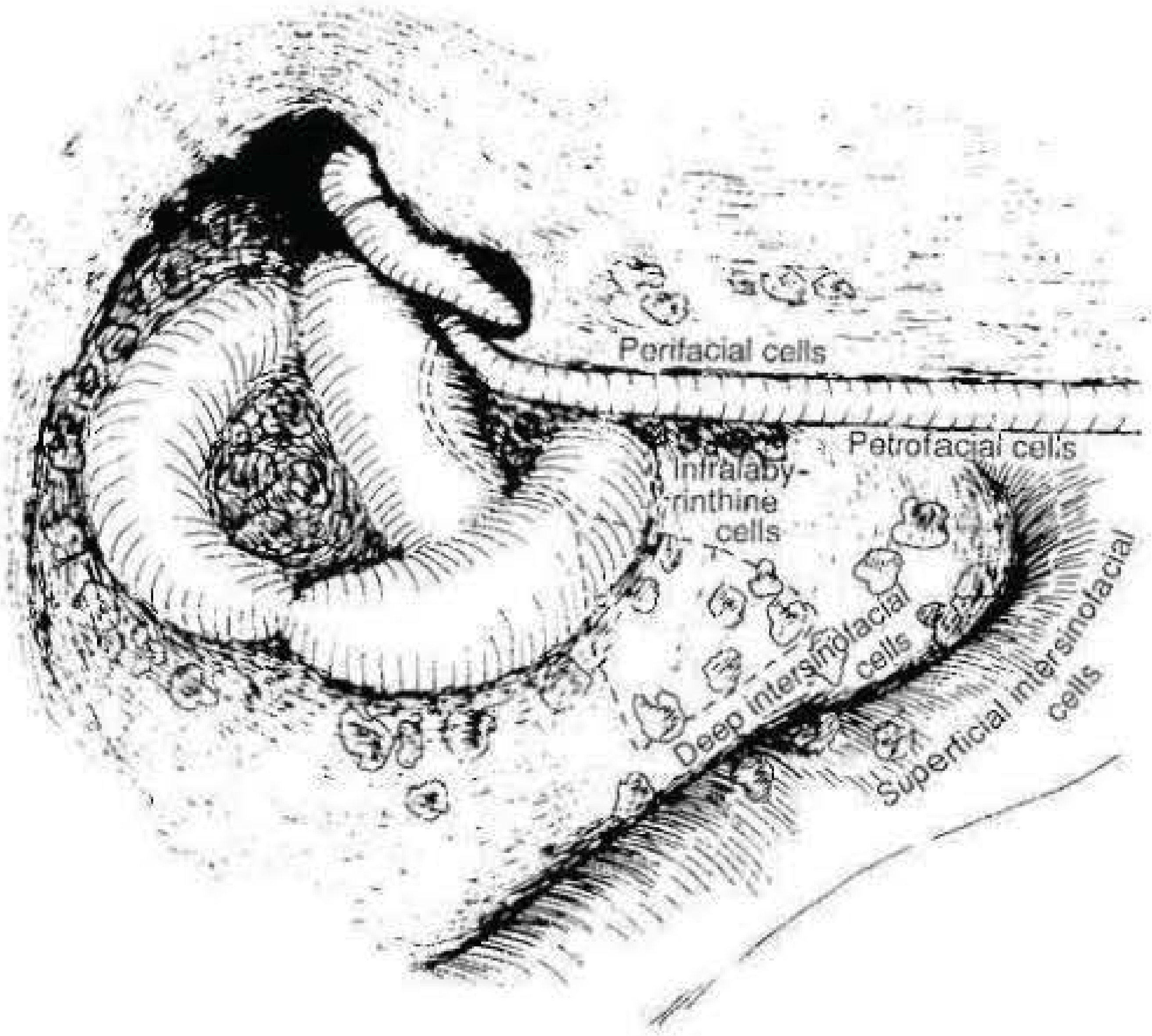


Fig. **120** **The infralabyrinthine cells, deep and superficial intersinofacial cells, and perifacial cells in relation to the facial nerve, sigmoid sinus, and posterior semicircular canal**. The endolymphatic sac and duct are indicated by dashed lines

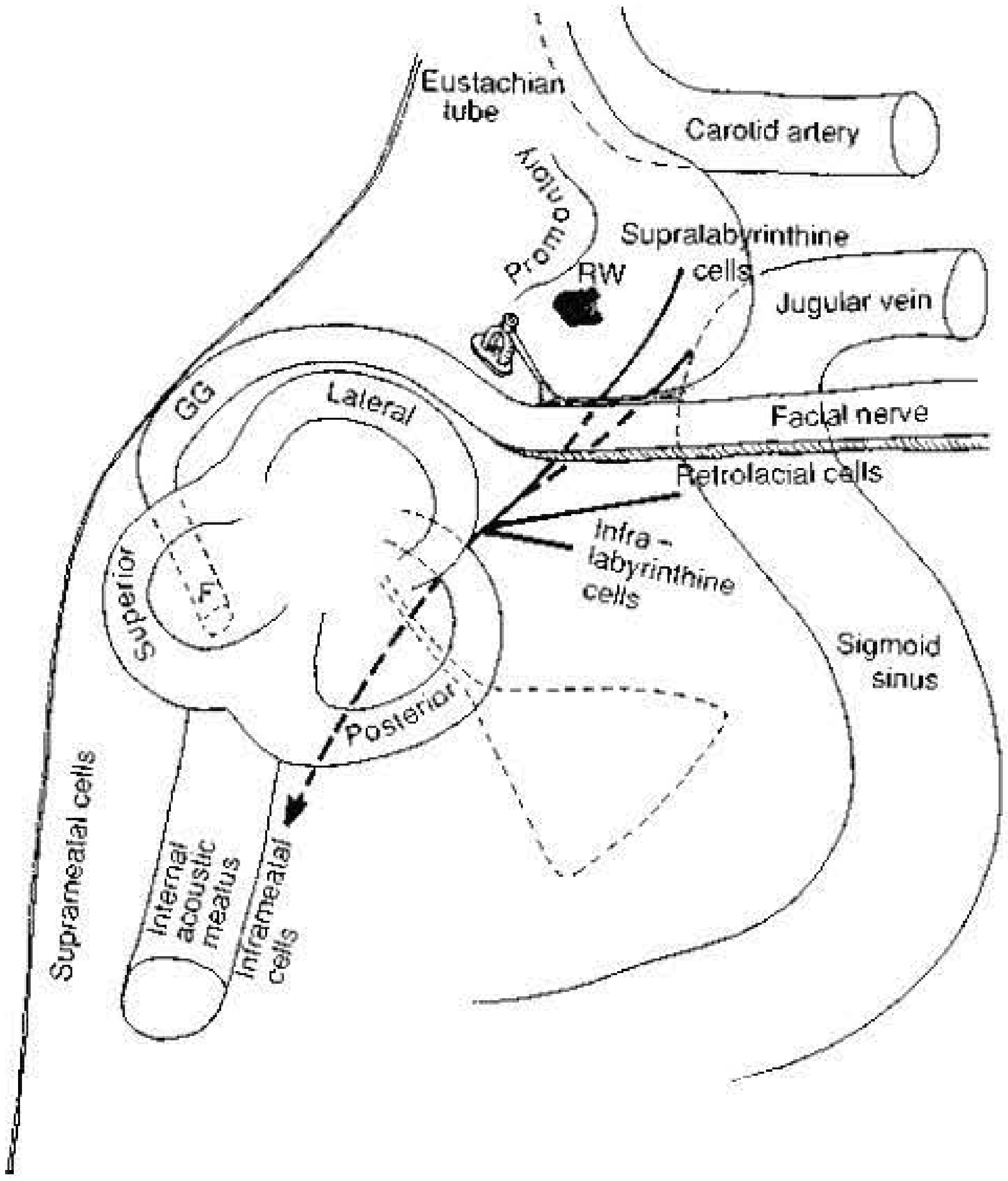


Fig. **121** **The connections from the sublabyrinthine cells** anteriorly to the facial nerve and the retrofacial and infralabyrinthine cells and inframeatal cells. GG: geniculate ganglion; F: facial nerve; RW: round window

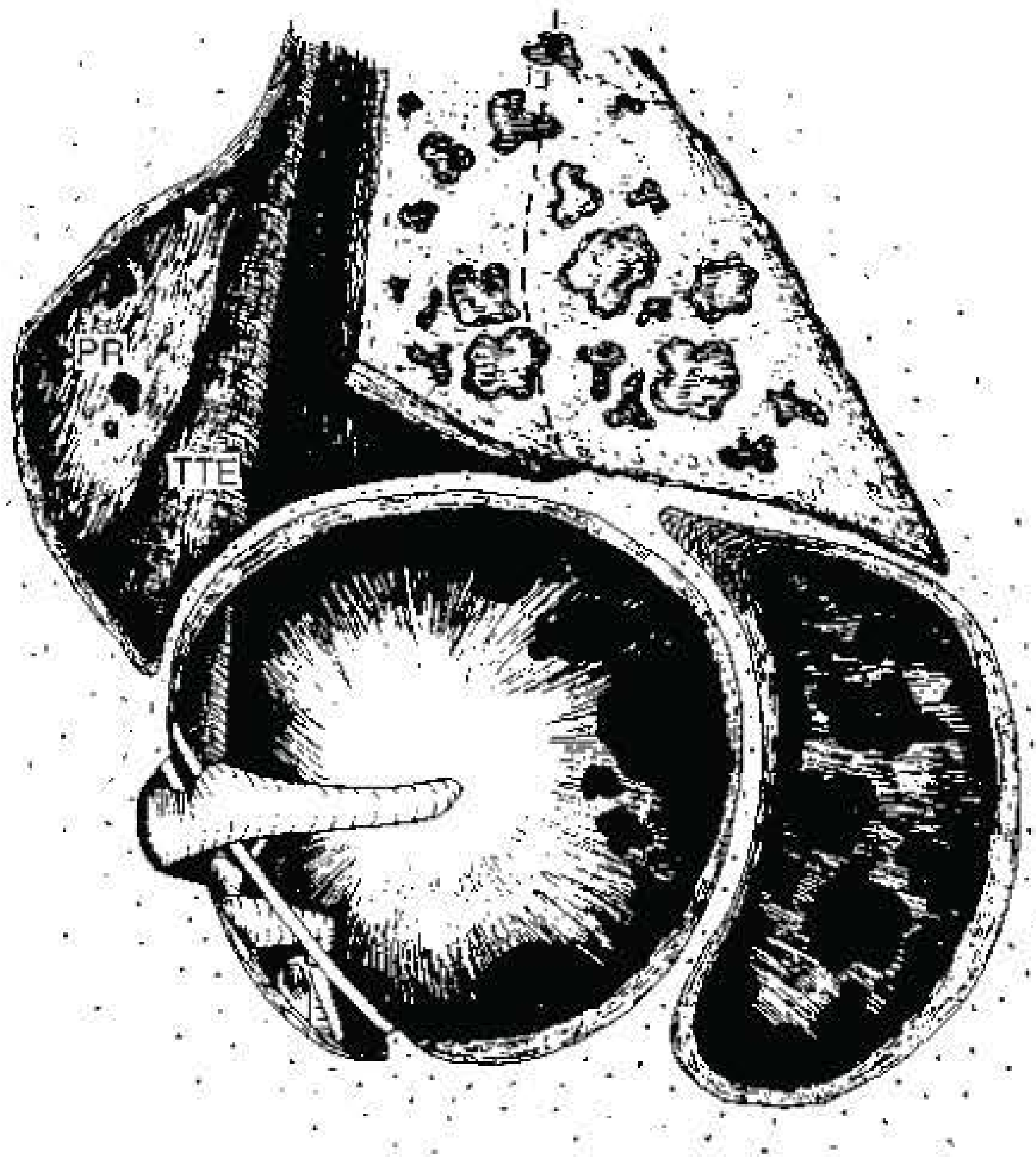


Fig. **122** **The lateral precochlear cells**, lying around the lateral wall of the Eustachian tube, with good intercellular connections to the hypotympanic cells and medial precochlear cells. TTE: eminence of the tensor tympani muscle; PR: pretubal recess

Precochlear or Inferior Prelabyrinthine Cell Tracts

The precochlear cells lie anterior to the cochlea. They originate from the anterior and inferior parts of the tympanum as well as the Eustachian tube.

The small *anterolateral* air cells occupy the space around the lateral lamina of the Eustachian tube (Fig. **122**). They communicate with the hypotympanic air cells and the medial precochlear cells, but they do not communicate directly with the cells of the petrous apex.

The *medial* precochlear cells lie between the carotid artery, the cochlea, and the Eustachian tube (Fig. **123**). They are called *peritubal cells, pericarotid cells,* and *intercaroticocochlear cells* (Proctor 1989). They originate from the anterior region of the hypotympanum and the Eustachian tube. The anteroinferior part of the petrous bone contains the cochlea and the canal of the carotid artery, which is angulated like the elbow at a right angle to its vertical part, which passes inferior to the petrous bone, running superiorly toward the tympanum, parallel to the jugular vein (Figs. **123, 124**).

In temporal bones with extensive pneumatization, air cells between the cochlea and the carotid canal, as well as around the bony part of the Eustachian tube and around the carotid canal may be seen. In ears with little or no pneumatization, the cochlea may be in direct contact with the carotid canal, and hence there are no air cells between them.

The hypotympanum communicates with the air cells of the petrous apex through the *anteroposterior air cell tract,* which connects both cells lying anterior to the carotid canal and cells lying posterior to the canal.

The *anteroinferior route* to the petrous apex passes from the precochlear region in the hypotympanum via the peritubal cells and pericarotid cells to the apex.

Clinical Importance of Cell Tract Connections

In cases of attic cholesteatoma involving the entire attic and antrum, the mastoid cells are often ventilated, despite the obstruction to ventilation through the tympanic isthmus and the attic. In such cases, the mastoid cells can theoretically be ventilated by three possible routes.

1. From the hypotympanum via the infralabyrinthine and retrolabyrinthine cells (Figs. **119–121**). This route would seem to be the simplest and most direct way.

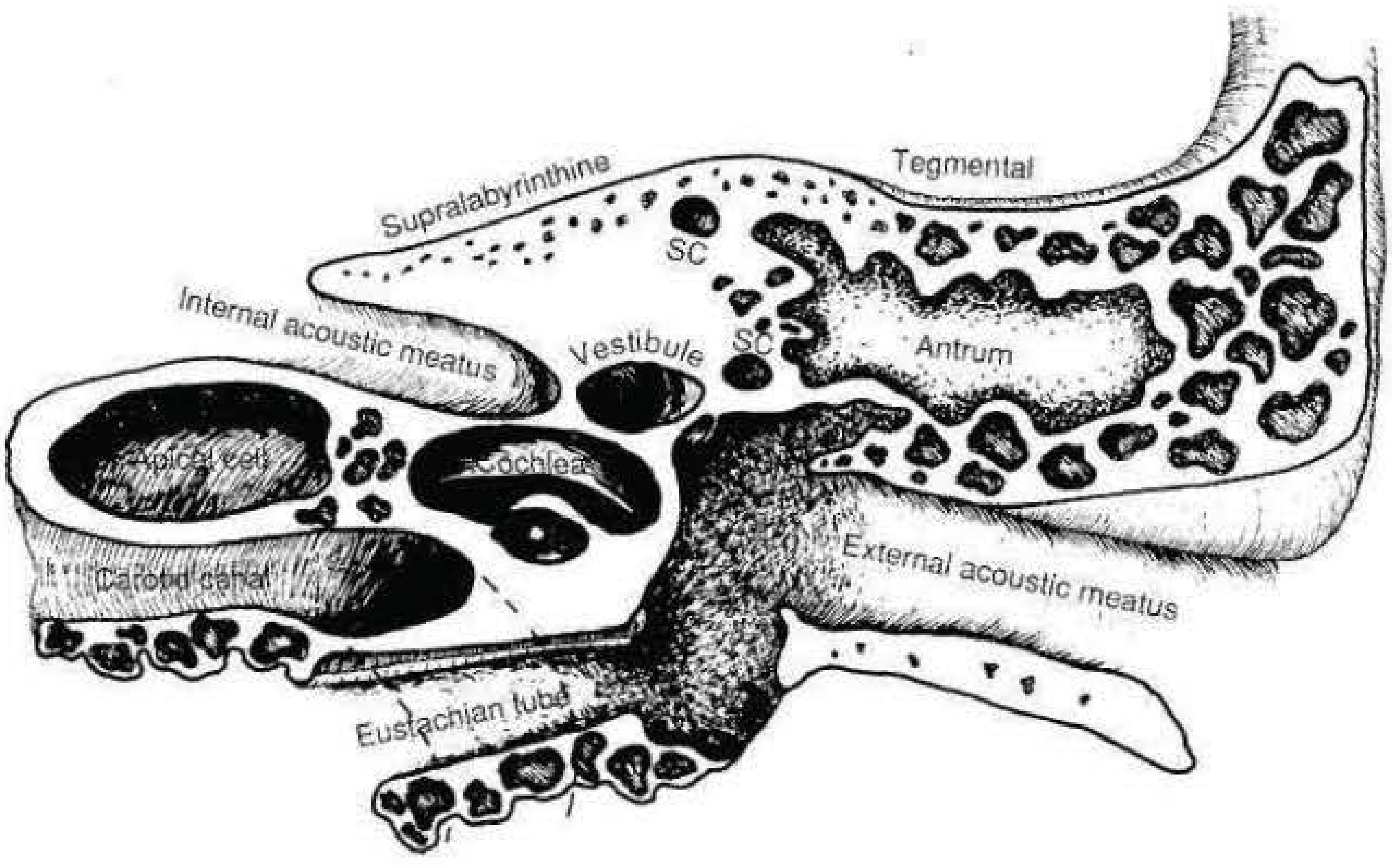


Fig. **123** **Frontal section through the right temporal bone**. A large apical cell, peritubal cells inferior to the Eustachian tube, and pericarotid cells between the carotid canal and the Eustachian tube, as well as a few corticocochlear cells between the cochlea (C) and the carotid canal. SC: superior semicircular canal. In the mastoid process, the tegmental and periantral cells around the antrum are visible

2. From the hypotympanum via the precochlear cells, apical cells, and infralabyrinthine cells, and then to the mastoid cells (Figs. **121, 124**).

3. The third possibility is from the hypotympanum via precochlear cells, apical cells, supralabyrinthine or retrolabyrinthine cells toward the mastoid air cells (Fig. **118**).

The existence of these connections is evident in several other situations.

A. In atelectasis or posterosuperior retraction with blockage of the tympanic isthmus, the air cells of the mastoid process are often ventilated.

B. In the fenestration operation, the apical air cells are usually not removed, and yet they remain mostly well ventilated.

C. After a canal wall–down mastoidectomy and blockage of all connections between the tympanic cavity and the mastoid process using either the open technique or one of the obliteration techniques, the mastoid air cells that have not been removed sometimes remain ventilated by one of the routes mentioned above.

D. In canal wall–down mastoidectomy, the perilabyrinthine cells are often not completely removed, in well-pneumatized cases. The same is often the case with the retrolabyrinthine, infralabyrinthine, and perifacial cells, as well as with the deep apical cells, yet these cells usually remain ventilated.

E. When performing total reconstruction of old radical cavities due to tympanic cavity problems, one may be surprised at how well ventilated the residual air cells appear to be in the mastoid tip, and at the normal appearance of the mucosa.

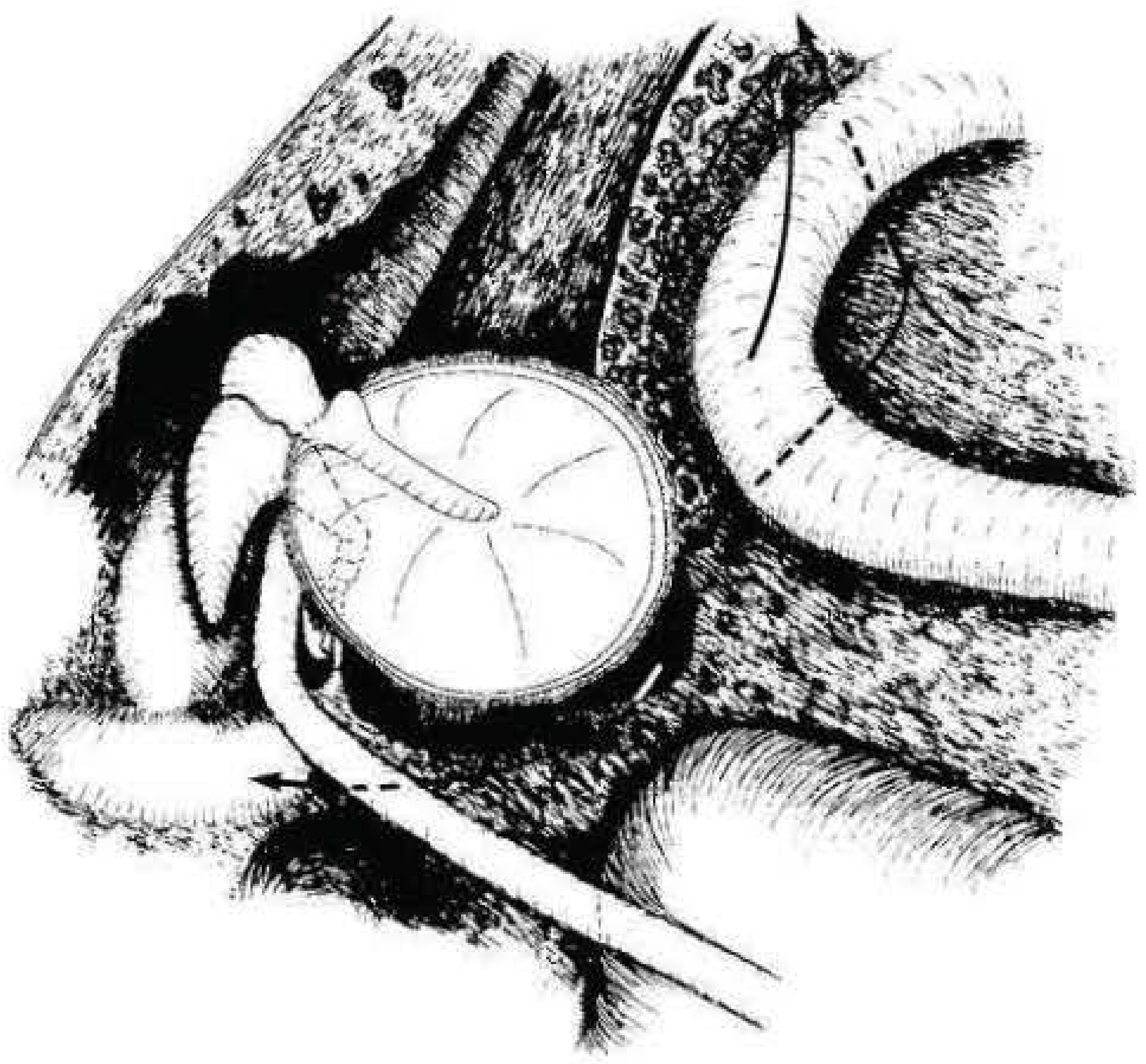


Fig. **124** **The connections between the pericochlear and pericarotid cells, and between the peritubal air cells and the apical cells**. For anatomical explanation see Fig. **121**

Another important feature of air cell tracts is the risk of cerebrospinal fluid rhinorrhea, for instance following acoustic neuroma surgery. In translabyrinthine acoustic neuroma surgery, it is evident that cerebrospinal fluid leakage sometimes occurs through the large perimeatal cells directly to the petrous apex and then to the hypotympanum (Fig. **125**). We therefore obliterate these cell groups separately (Tos and Thomsen 1991). We have noticed that obliteration of the cavity after translabyrinthine surgery without obliteration of the perimeatal cells does not always prevent cerebrospinal fluid leakage. Some surgeons, in translabyrinthine acoustic neuroma surgery, prefer a canal wall–down mastoidectomy technique in order to obliterate the Eustachian tube and tympanic cavity, as well as removing the ear drum and the ear canal skin, thus closing the external acoustic meatus.

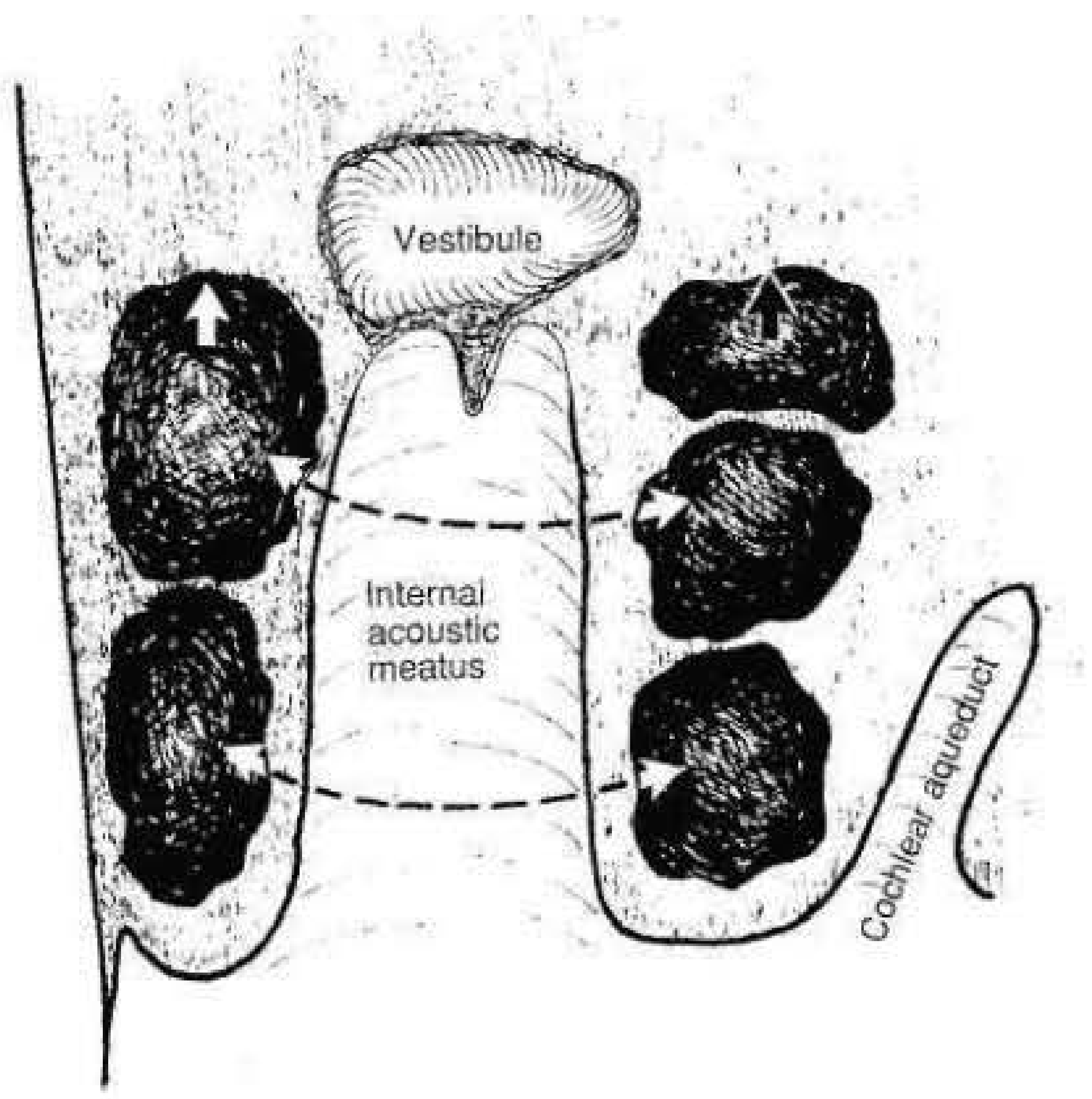


Fig. **125** **Large suprameatal and inframeatal air cells** around the opened internal acoustic meatus, with evident intercellular connections around the meatus (dashed arrows) to the apical cells, and with connections to the hypotympanum (arrows).TC: transverse crest (TC)

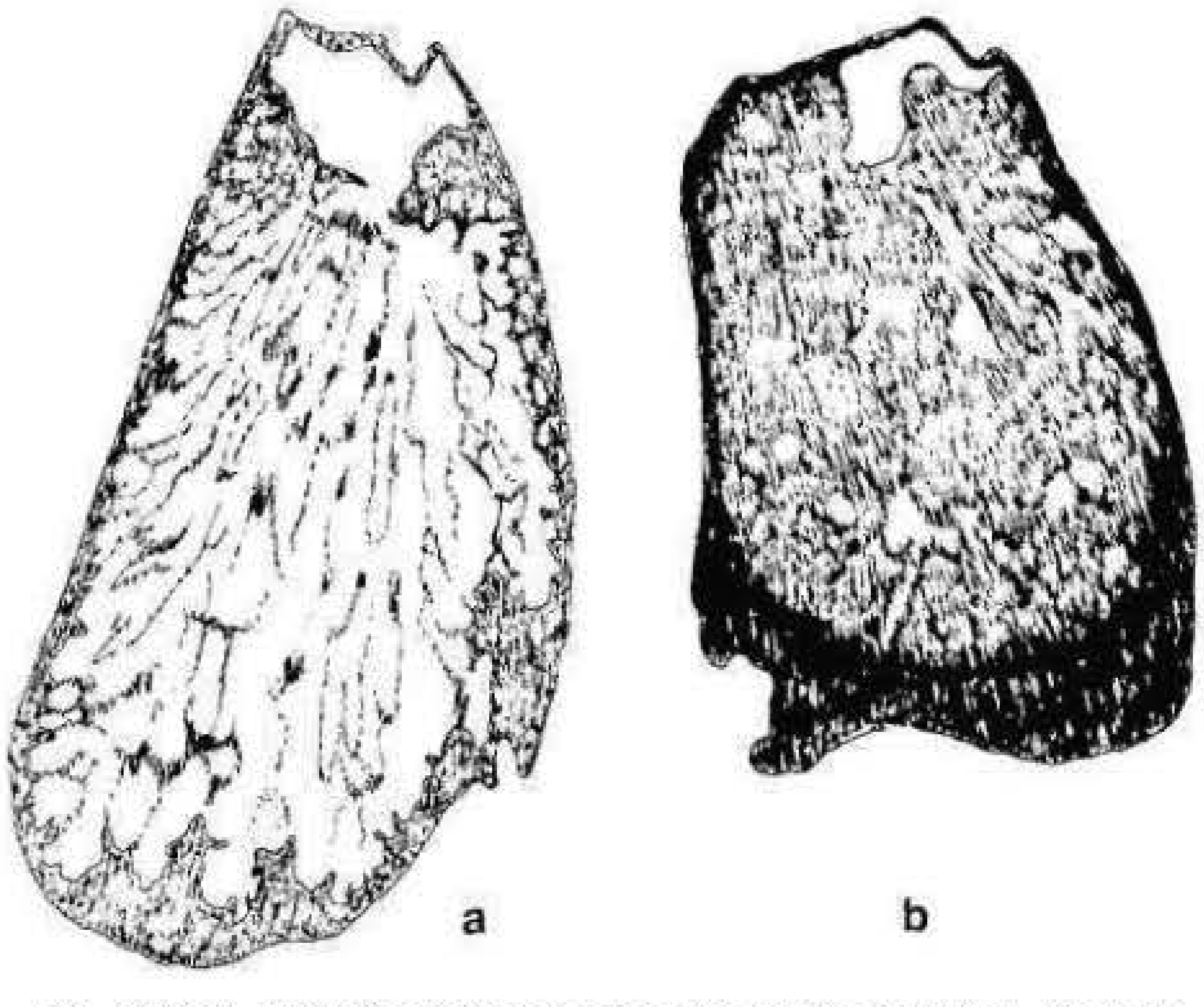


Fig. **126a** Uninfected ear of a six-moth-old pig. Normal mastoid process and normal pneumatization, with thin trabeculae, large air cells, and thin cortical bone.
b Constricted mastoid process on the right side in the same pig, infected at the age of one week by instillation of glycerin into the tympanic cavity, creating a tubal occlusion. The mastoid process is shorter, the cortical bone is thick, the air cells are small, and the trabeculae are thick, showing hampered growth and hampered pneumatization. Both of these are sequelae of infection

The Constricted Mastoid Process

A short mastoid process, a low-lying dura, a small antrum, and a narrow space within the mastoid process with thick cortical bone containing few or no air cells, are the characteristics of the "constricted mastoid process." An anteriorly positioned sigmoid sinus and a high jugular bulb are often associated with the constricted mastoid process. Some authors (Heermann and Riehm 1961) have found an association between hypocellularity and an anteriorly positioned sigmoid sinus, we have confirmed a clear tendency (Turgut and Tos 1992 a).

The constricted mastoid process is often found in cases of cholesteatoma and adhesive otitis media. This connection has therefore, with reasonable logic, been treated as a cornerstone for the genetic theory (Diamant 1952). However, experimental studies on pigs have demonstrated histologically that inflammation of the middle ear inhibits the normal process of pneumatization, and thus leads to hypocellularity of the mastoid process (Aoki et al. 1986, Ikarashi and Nakano 1987). Recent experimental studies on pigs have also shown that an early infection, e. g., two to seven days after birth, results in a significantly smaller mastoid process on the infected side, with a shorter length and area of the mastoid process, remarkable hypocellularity, and increased thickness of the cortical bone (Aoki et al. 1990). It has thus been clearly demonstrated that a constricted mastoid process is not an anatomical variation but a result of infection (Fig. **126**). The infection not only inhibits the pneumatization but also the growth of the mastoid process.

In addition to this disturbance of pneumatization in humans, *sclerosis* of the mastoid process occurs due to chronic infection. Formerly well-pneumatized mastoid cells can become sclerotic and obliterated due to new formation of bone in chronic otitits media (Palva and Palva 1966). It has been shown experimentally that an infected rat bulla becomes thicker due to new bone formation, which starts three weeks after infection (Tos 1981 a, van der Beek and Kuijpers 1984).

This is often the case in cholesteatoma and chronic noncholesteatomatous otitis media in adults. The poorly developed mastoid air cells become even more sclerotic, and are eventually obliterated due to chronic infection. They may totally disappear, which explains why cholesteatoma in adults is often surrounded by very compact bone. Often after mastoidectomy for adult cholesteatoma, a small mastoid cavity with smoothed walls is the result, and this contrasts with the situation in children with a relatively short history of cholesteatoma disease. Here the cholesteatoma often invades the relatively well-developed perilabyrinthine cells, making childhood cholesteatoma appear more aggressive than adult cholesteatoma.

The Question of Cause and Effect

During the last 50 years, there has been much debate in otology regarding the question: What is the cause and what is the effect in middle ear pathology? The pneumatization of the temporal bone has been involved in several of the controversies. As summarized in this chapter, histopathological research on middle ear mucosa over the last 25 years and epidemiological research into secretory otitis media over the last 15 years, together with planimetric measurements of mastoid air cells in the epidemiological material (Tos 1981 b), have clarified some of the cause and effect issues (Table **3**).

At birth the middle ear status is normal, and there are no air cells in the mastoid process. During infancy and early childhood, the very common respiratory tract infections are the dominant cause of secretory otitis media and long-lasting intrinsic tubal dysfunction, which occurs at least once in about 90% of preschool children. Secretory otitis media and chronic tubal dysfunction cause, on the one hand, the drum sequelae, such as atrophy and retraction, and on the other hand inhibit the process of pneumatization, resulting in hypocellularity (Table **3**). In addition, secretory otitis media causes sequelae in the middle ear mucosa, such as epithelial changes, with the presence of mucous glands, adhesions, and some mucosal folds.

There is a highly significant correlation between drum sequelae and hypocellularity (Table **3**), and several researchers earlier concluded that the drum changes may be sequelae of hypocellularity. Today it is well documented that both the hypocellularity and the drum changes are sequelae of the same diseases in childhood, these being chronic secretory otitis media, chronic tubal dysfunction, and acute suppurative otitis media.

The most severe drum changes may progress to chronic otitis media, i.e., the atrophic drum may perforate, resulting in chronic otitis media with the risk of infection and active chronic otitis media (Tables **3**, **4**). Retraction of the atrophic drum may progress to adhesive otitis media, sinus cholesteatoma, or tensa retraction cholesteatoma, and an attic retraction may progress to attic precholesteatoma and eventually attic cholesteatoma.

The hypocellularity and constricted mastoid process found in cases of cholesteatoma are the most severe sequelae of the disturbed pneumatization process caused in early childhood by infection and chronic secretory otitis media, which also result in severe drum changes and chronic middle ear disease (Tables **3**, **4**). Thus, the highly significant correlation between a constricted mastoid process and cholesteatoma is explained (Tos 1990 a). Some of the pathogenetic aspects of chronic middle ear diseases are described in Volume 1, Chapter 9.

Table **3** Cause and sequela problems in otology

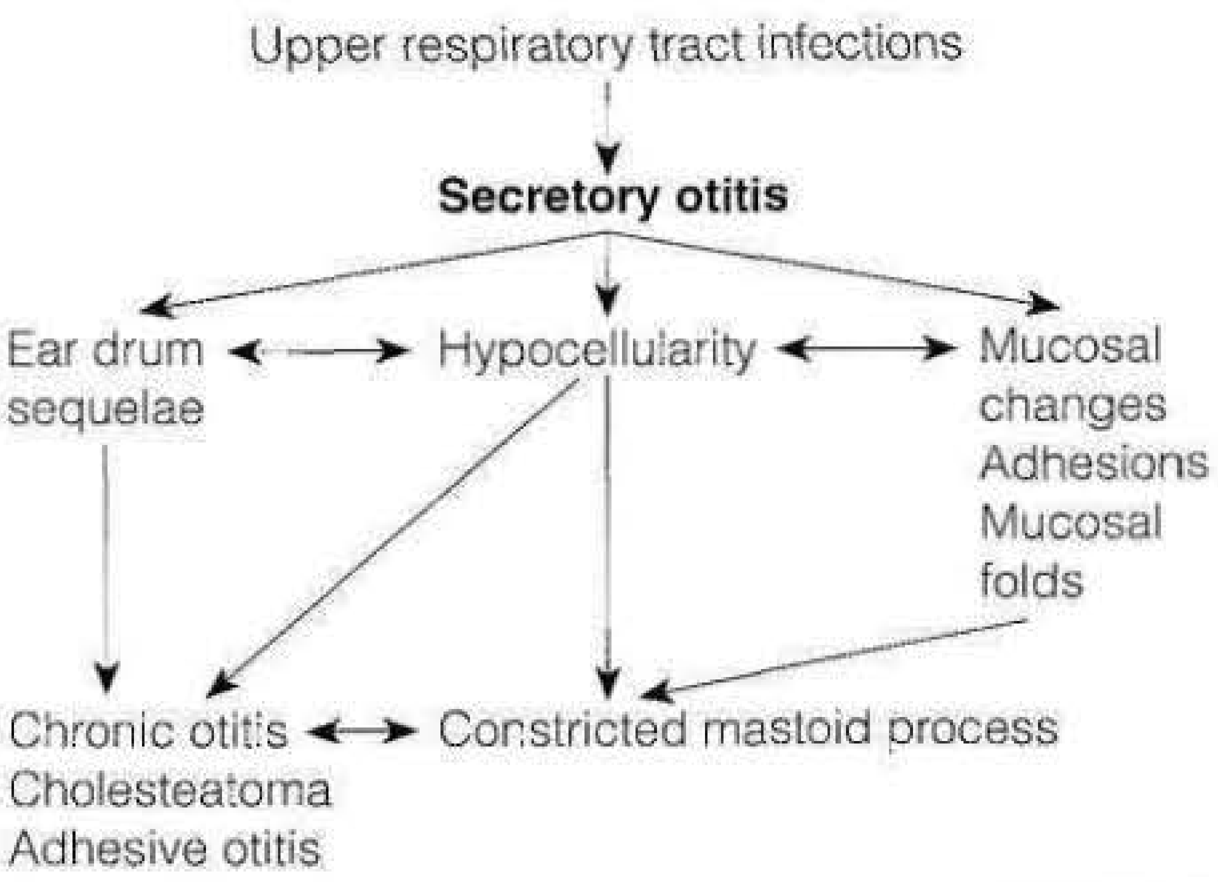
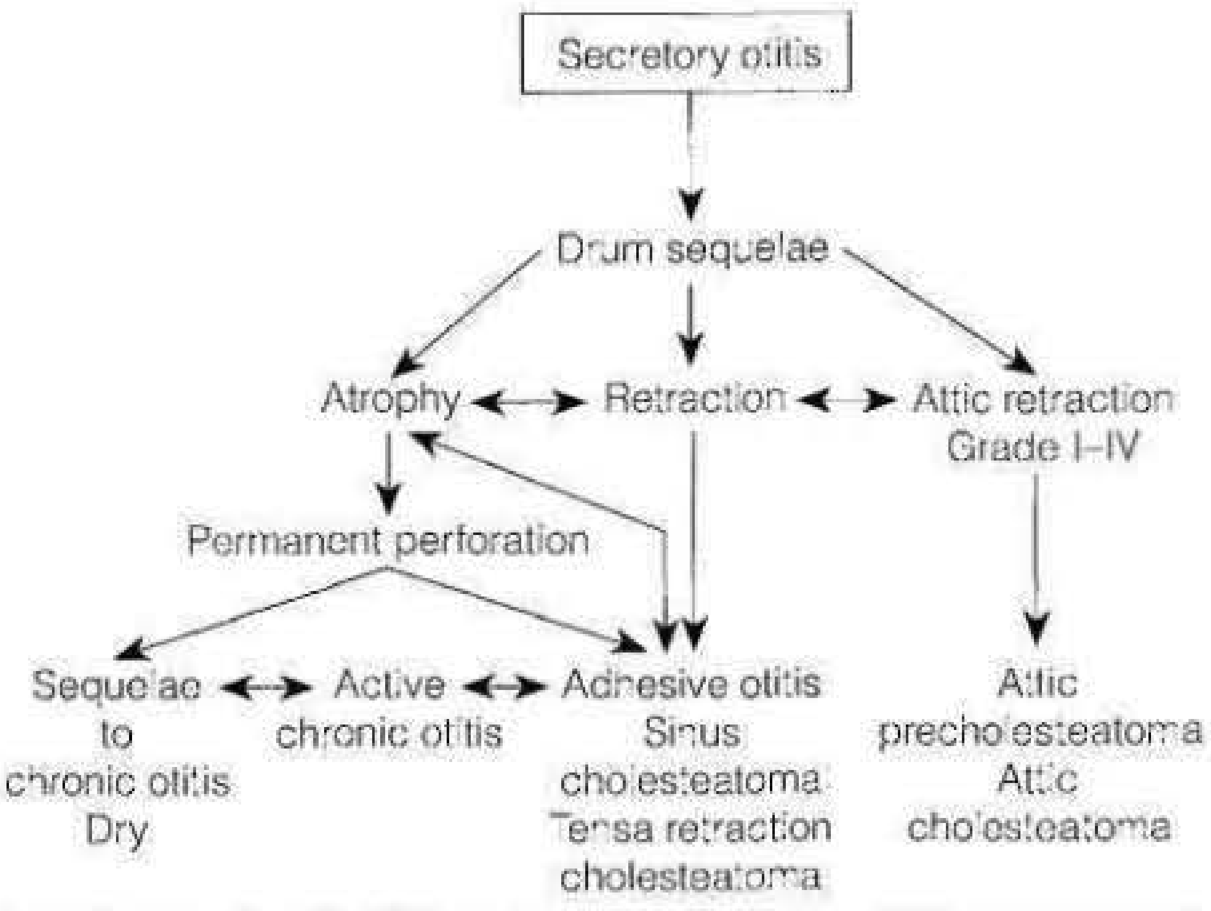

Upper respiratory tract infections
Secretory otitis
Ear drum sequelae
Hypocellularity
Mucosal changes
Adhesions
Mucosal folds
Chronic otitis
Cholesteatoma
Adhesive otitis
Constricted mastoid process

Table **4** Progression of ear drum sequelae after chronic secretory otitis


Secretory otitis
Drum sequelae
Atrophy
Retraction
Attic retraction Grade I–IV
Permanent perforation
Sequelae to chronic otitis Dry
Active chronic otitis
Adhesive otitis
Sinus cholesteatoma
Tensa retraction cholesteatoma
Attic precholesteatoma
Attic cholesteatoma

4 Basic Mastoidectomy Techniques

The Drilling Techniques

Every ear surgeon—myself included—has caused unnecessary damage to structures during drilling; nearly all of this could be avoided if one respected the basic principles of drilling at the time of the damage. Drill damage is most common with a cutting burr, but can occur with other instruments such as the chisel, curette, rongeur, and rougine. The instrumental trauma can result in damage to the ossicles, inner ear, facial nerve, venous sinuses, or dura.

Damage Resulting from the Cutting Burr

Damage from a cutting burr is much more common than from a diamond burr, for several reasons. The cutting burr is rougher, and can fracture the bone. The cutting burr always damages the soft tissues when touching them, whereas the diamond burr seldom damages the soft tissues, and it only happens when the burr head is pressed onto the tissues in such a way that the tissues cannot escape. The damage a cutting burr causes is not always severe, but is usually unnecessary and can be dangerous. The damage, in order of site frequency, affects soft tissue, canal skin, dura, ossicles, venous sinuses, semicircular canals, facial nerve, and oval and round windows.

Damage to Soft Tissue

This includes damage to the soft tissue surrounding the surface of the mastoid process, the temporalis muscle, the ear canal skin, and the soft tissue of the incision. Such damage occurs if drilling takes place on a sharp edge of the cavity with the burr positioned wrongly (Fig. **127**). The sharp drill will slip into the temporalis muscle or into the ear canal, depending on which edge is being drilled, and in which direction the burr is rotating. To avoid the burr jumping from an edge, it should be placed perpendicular to that edge, and drilling should start slowly without pressure and with gentle movements of the burr up and down along the edge (Fig. **128**).

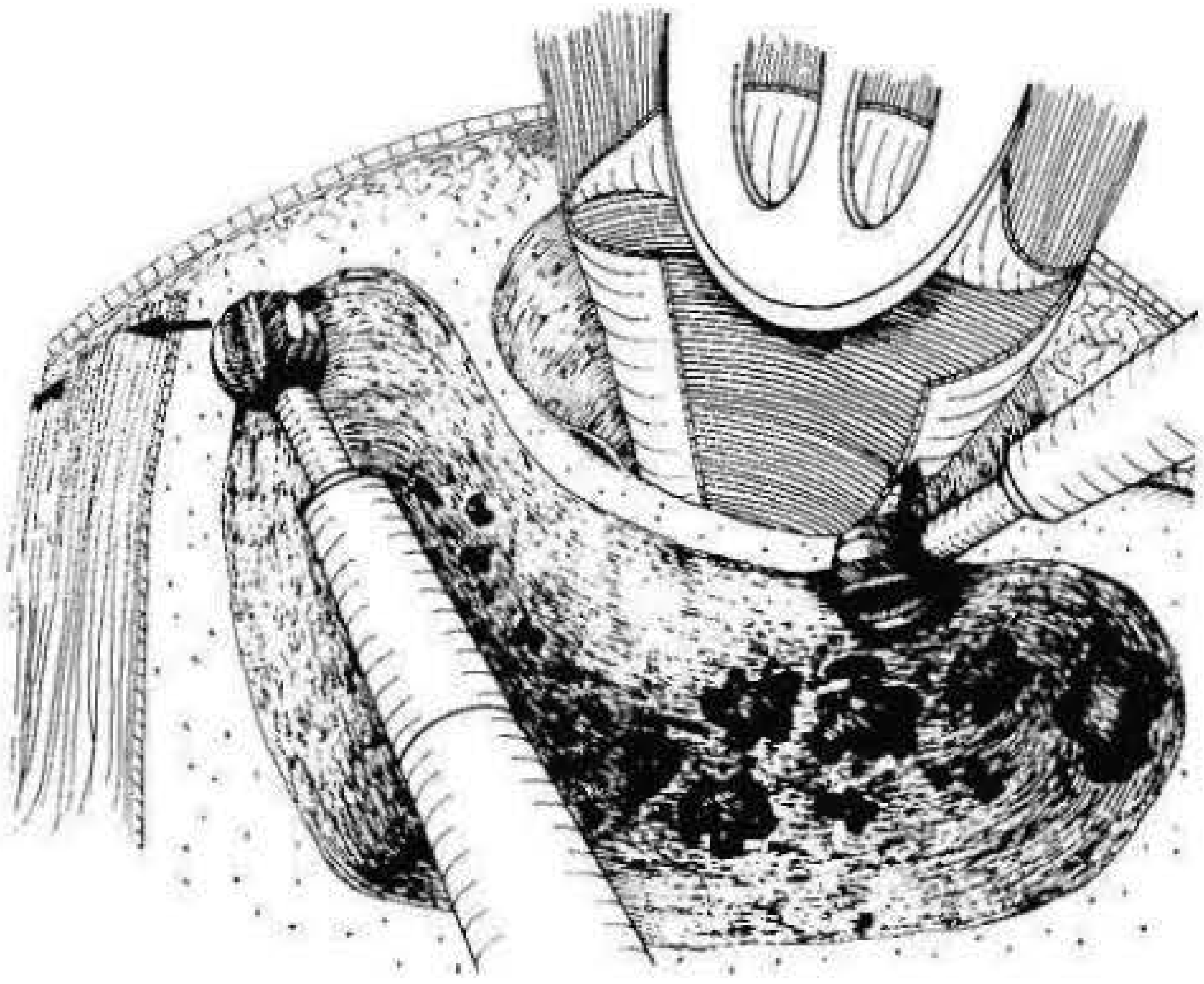


Fig. **127** **Incorrect drilling** with a cutting burr to the outer edge of the mastoidectomy cavity. The burrs are placed tangentially on the edges, and are displaced when rotating

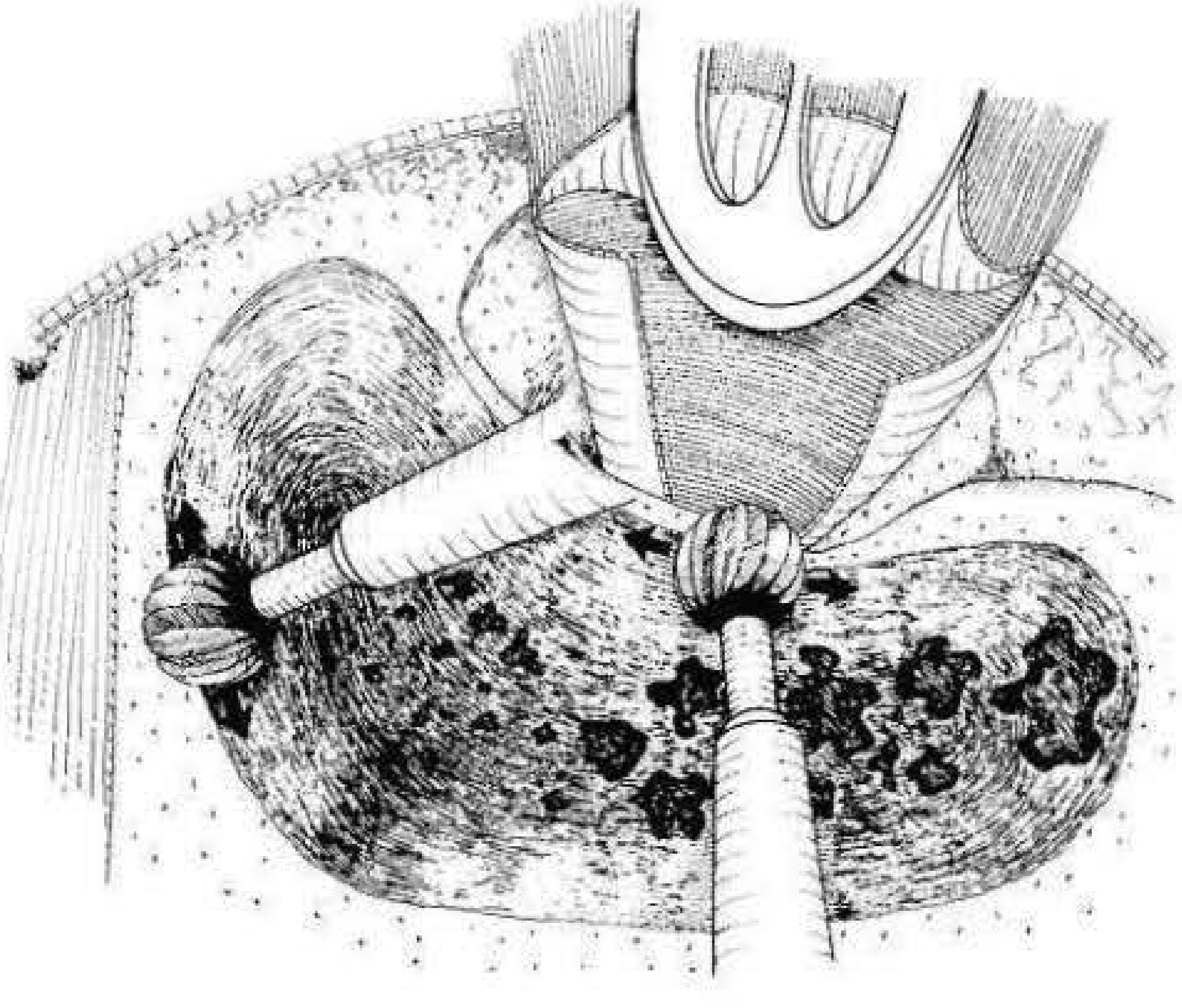


Fig. **128** **Correct drilling** of the edges by placing the cutting burr perpendicularly on the edge. When the burr is rotated, it moves along the edge, which is the purpose of this type of drilling

Damage to the Ear Canal Skin Flaps

Drilling with a cutting burr within the ear canal, either in retroauricular or endaural approaches, can damage the ear canal skin and tear off the base of a skin flap, especially if it is large, e. g., a Surdille flap in the Shambaugh (1980), Lempert (1941) or Farrior (1968) endaural incisions (Volume 1, pp. 24–33). Some surgeons therefore advocate removal of the ear canal skin as a routine procedure in the endaural approach (Farrior 1968, Wolfermann 1971) and replacement of the skin flaps either in the same place or elsewhere at the end of the operation.

Instead of removing the ear canal skin flaps, the present author prefers the use of a diamond burr within the ear canal when in the vicinity of the canal skin. Protecting the skin flaps by pushing them anteriorly into the anterior tympanomeatal angle, or using retractors with protecting blades, is also a good solution to this problem.

Exposure of the Dura

Exposure of a few square millimeters of the middle fossa dura in the lateral part of the mastoid tegmen (Fig. **62**) is sometimes desirable and necessary in order to locate the superior border of the mastoid process. This deliberate small dural exposure is harmless in middle ear surgery, and can easily be performed at an early stage of the mastoidectomy through careful drilling, first with a cutting burr (Fig. **129**) and then with a diamond burr. When the compact bone of the middle fossa dura plate is reached, a slightly pinkish coloration can be seen through the bone, caused by dural vessels. After further drilling on this plate, the dura is exposed as a white area, and the level of the mastoid tegmen is located (Fig. **130**).

Sometimes, especially with a low-lying dura and attic cholesteatoma, a larger area of the dura at the tegmen antri and tegmen tympani has to be exposed. When one is performing the intact canal wall technique, a very narrow space can be encountered between the bony ear canal—even if it is drilled extremely thin—and the low-lying dura, and the space hampers the view of an attic cholesteatoma (Fig. **131**). In such cases, the dura has to be exposed and gently displaced superiorly in order to

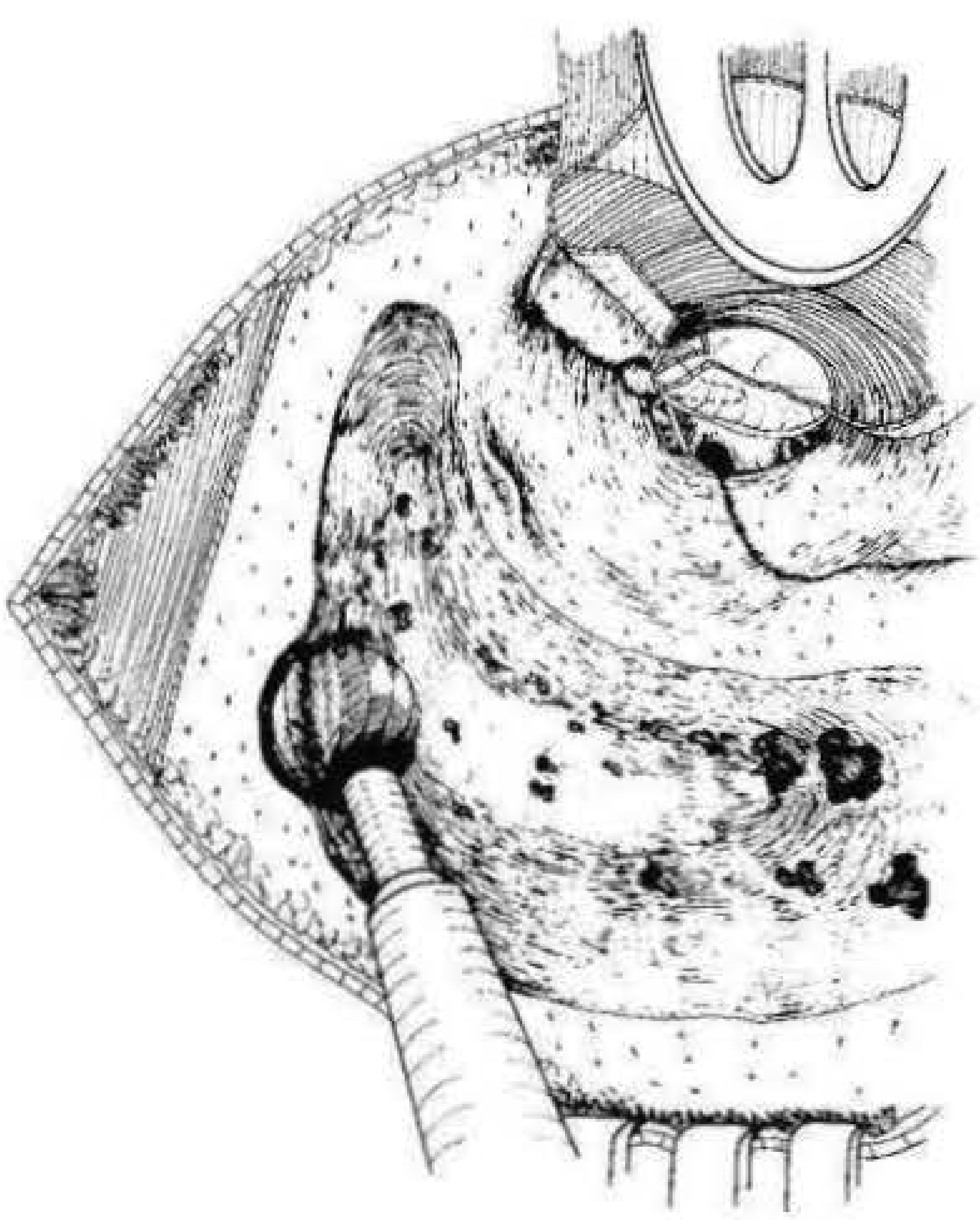


Fig. **129** **Exposure of the middle fossa dura** at the mastoid tegmen just under the cortical bone, in order to locate the level of the tegmen

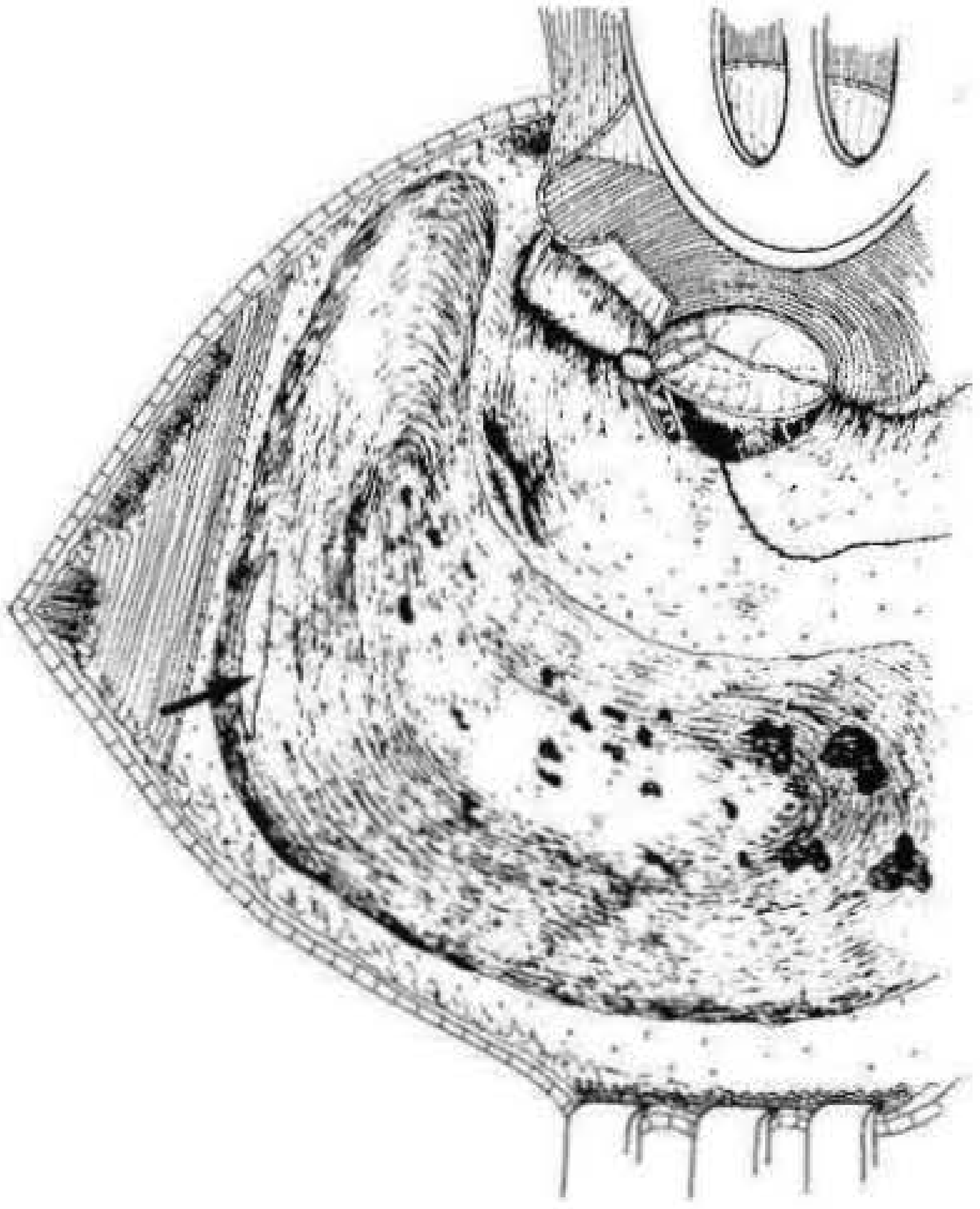


Fig. **130** A small area of the dura at the mastoid tegmen is exposed (arrow) in a canal wall–up mastoidectomy situation before penetration of Körner's septum and entry into the antrum

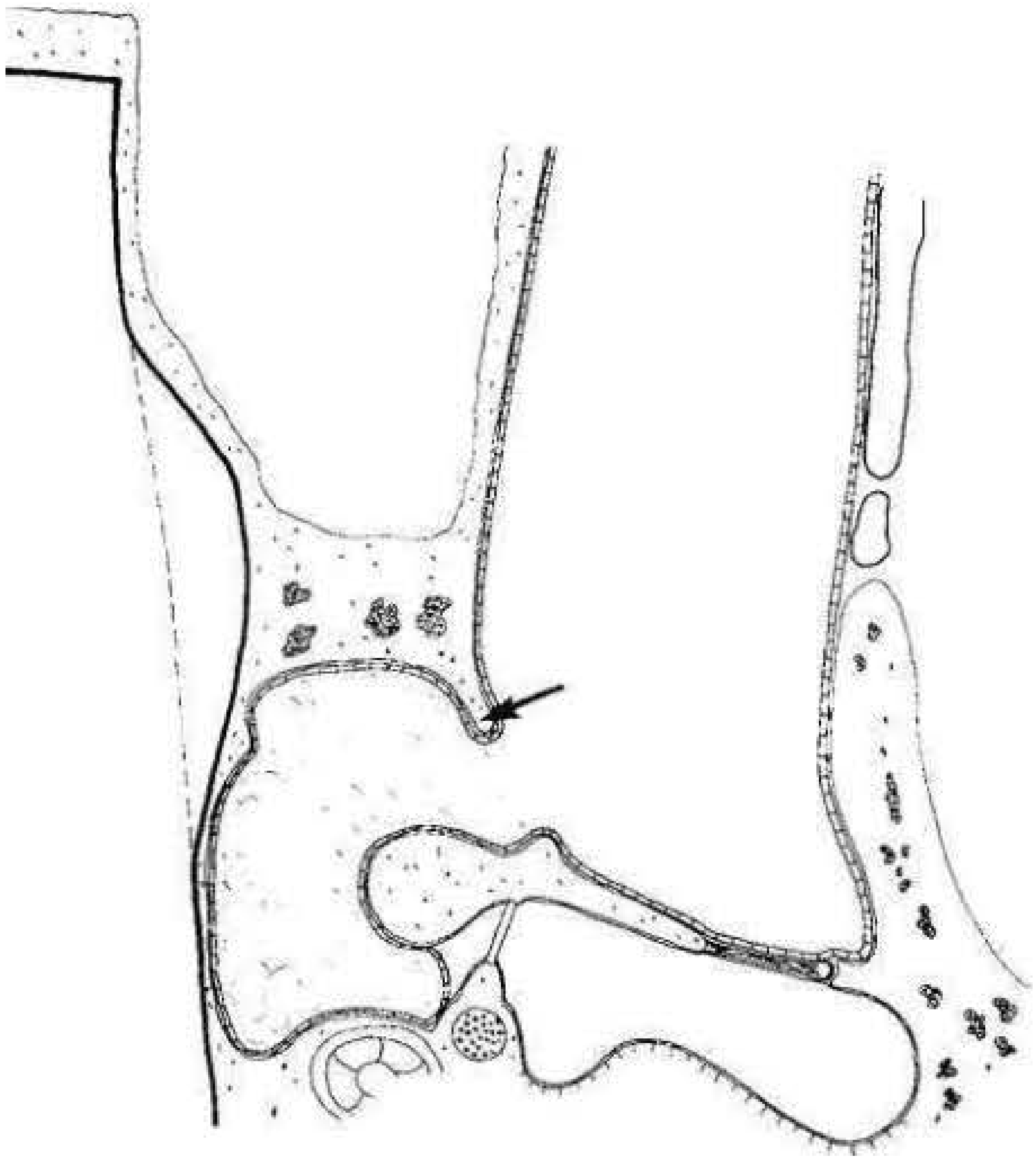


Fig. **131** **Side view of an attic cholesteatoma** surrounding the malleus head and eroding part of the scutum (arrow) in an ear with a low position of the middle fossa dura, hampering the view for safe removal of the cholesteatoma

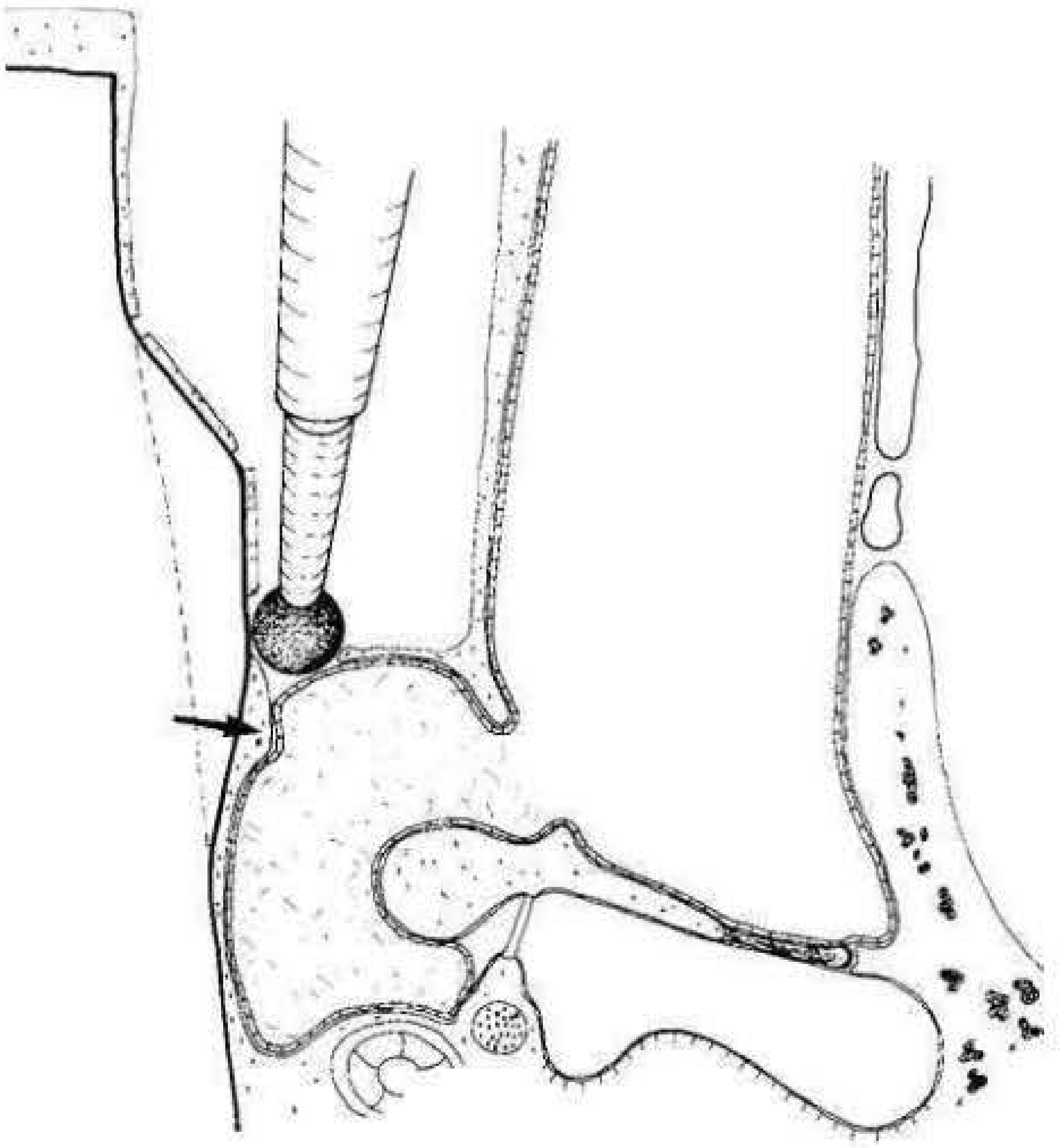


Fig. **132** The bony plate at the mastoid tegmen and tegmen antri is drilled thin with a diamond burr and fractured, allowing partial exposure of a bony overhang (arrow) of the tegmen antri and partial exposure of cholesteatoma matrix

continue safe drilling toward the attic cholesteatoma (Fig. **131**). The bony plate has to be drilled extremely thin using a large diamond burr (Fig. **132**). The resulting thin plate can then be fractured by pushing it superiorly (Fig. **133**), or partly removed by elevating it gently away from the dura with a broad elevator. The dura, which is now mobilized, can be gently pushed superiorly with the tip of the suction tube, allowing good visibility for further safe drilling of the bony protrusions and spicula using a diamond burr and safe elevation of the cholesteatoma matrix from the thin bony plate of the tegmen tympani (Fig. **134**). The result of these efforts will be the safe dissection of the cholesteatoma and a relatively small dural exposure, but with the dura itself remaining intact (Figs. **135, 136**). The exposed dura creates a risk of prolapse, but the risk is extremely small, and usually some new bone is formed, reducing or totally covering the exposed area of the dura.

It is unusual for exposure and mobilization of the middle fossa dura to be necessary, but it can always be performed as long as the largest possible diamond burrs are used. Perforation of the dura seldom occurs.

In our method of translabyrinthine surgery for acoustic neuroma (Tos and Thomsen 1991), total exposure and mobilization of the entire middle fossa dura and the posterior fossa dura has been performed as a routine procedure in 600 translabyrin-

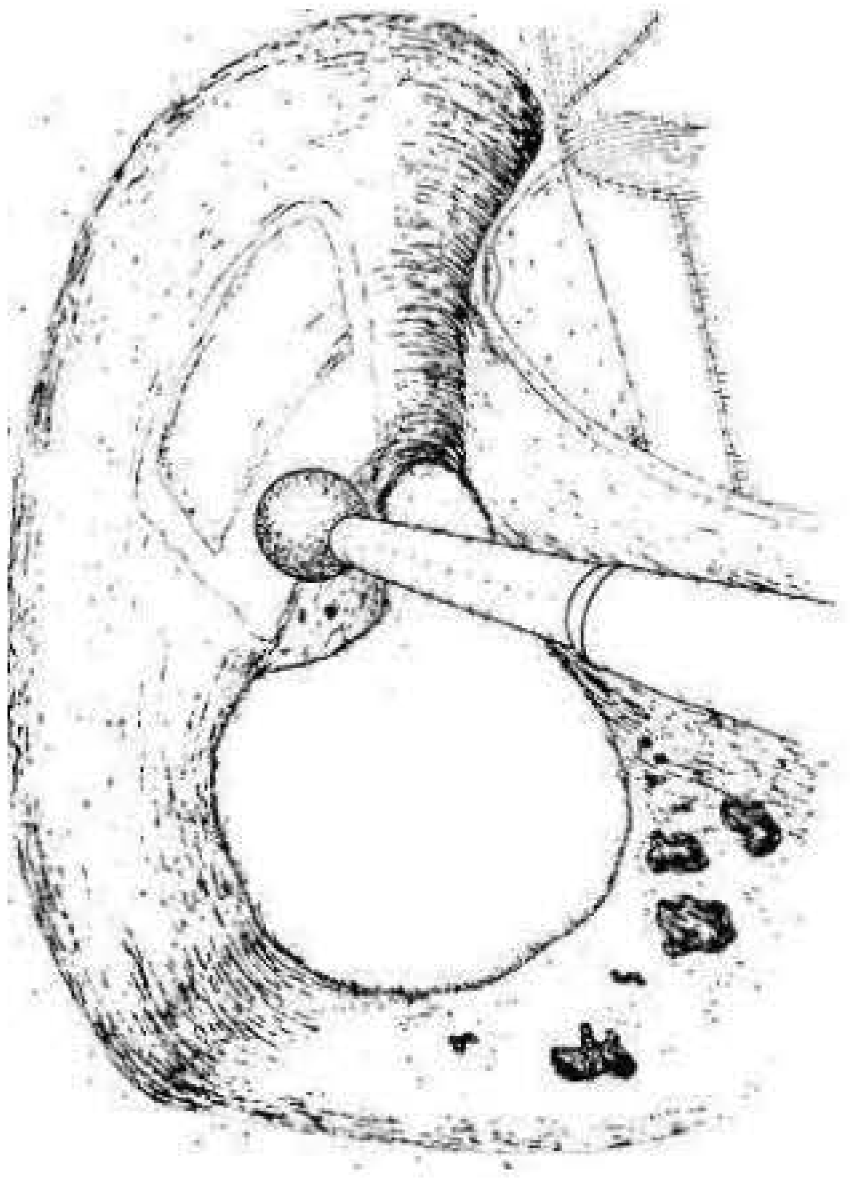


Fig. **133** **Intact canal wall mastoidectomy**, seen from behind, with an attic cholesteatoma in place. A bony plate of the mastoid tegmen is mobilized. The dura of the tegmen antri and the bony overhang hampering the view to the tegmen tympani are drilled away using a diamond burr

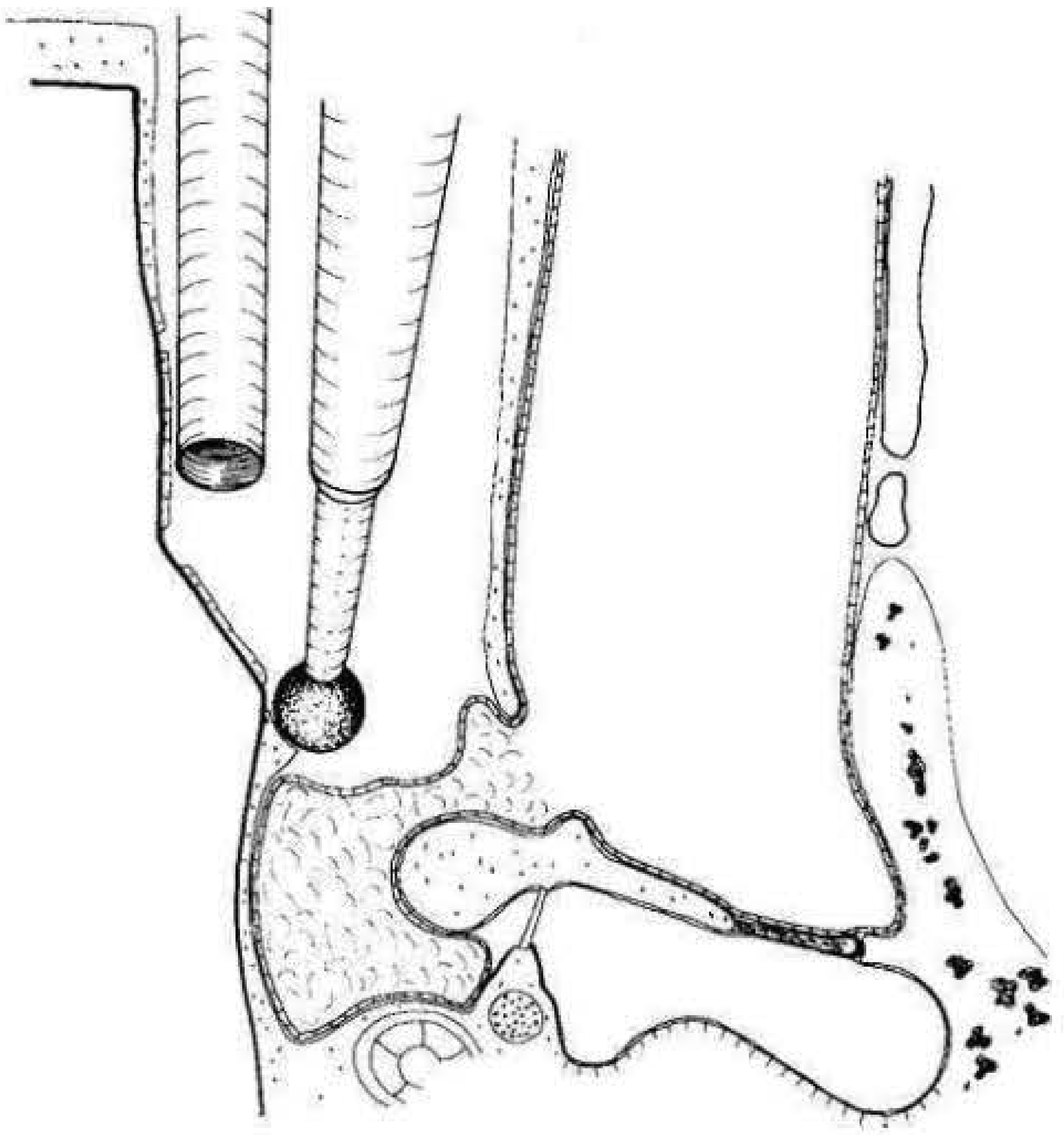


Fig. **134** The mobile dura is gently pushed superiorly with a suction tube, allowing one to drill off the bony overhang

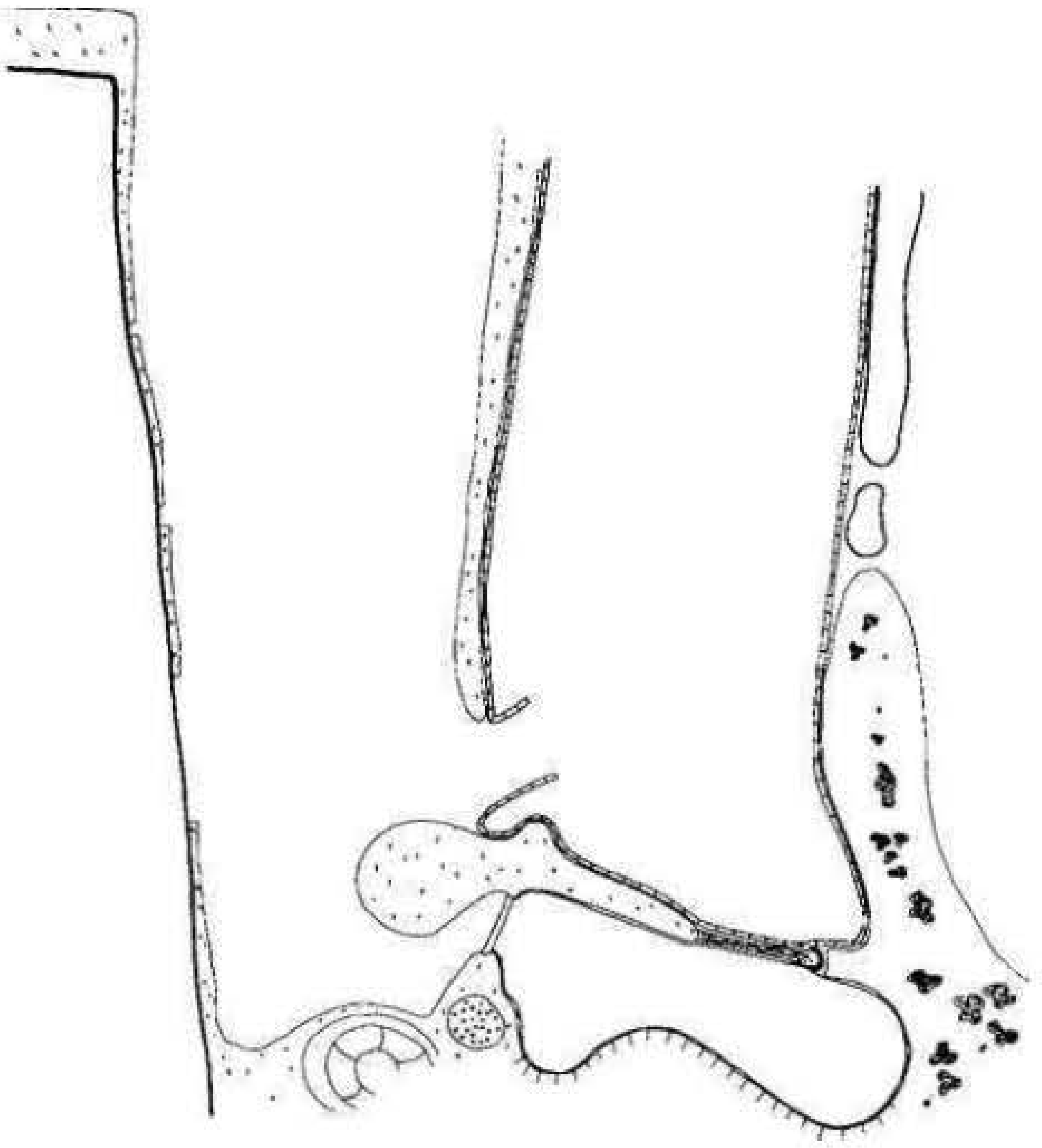


Fig. **135** The inferiorly positioned middle fossa dura is partly exposed and partly covered with thin bony plates, and the attic cholesteatoma is removed

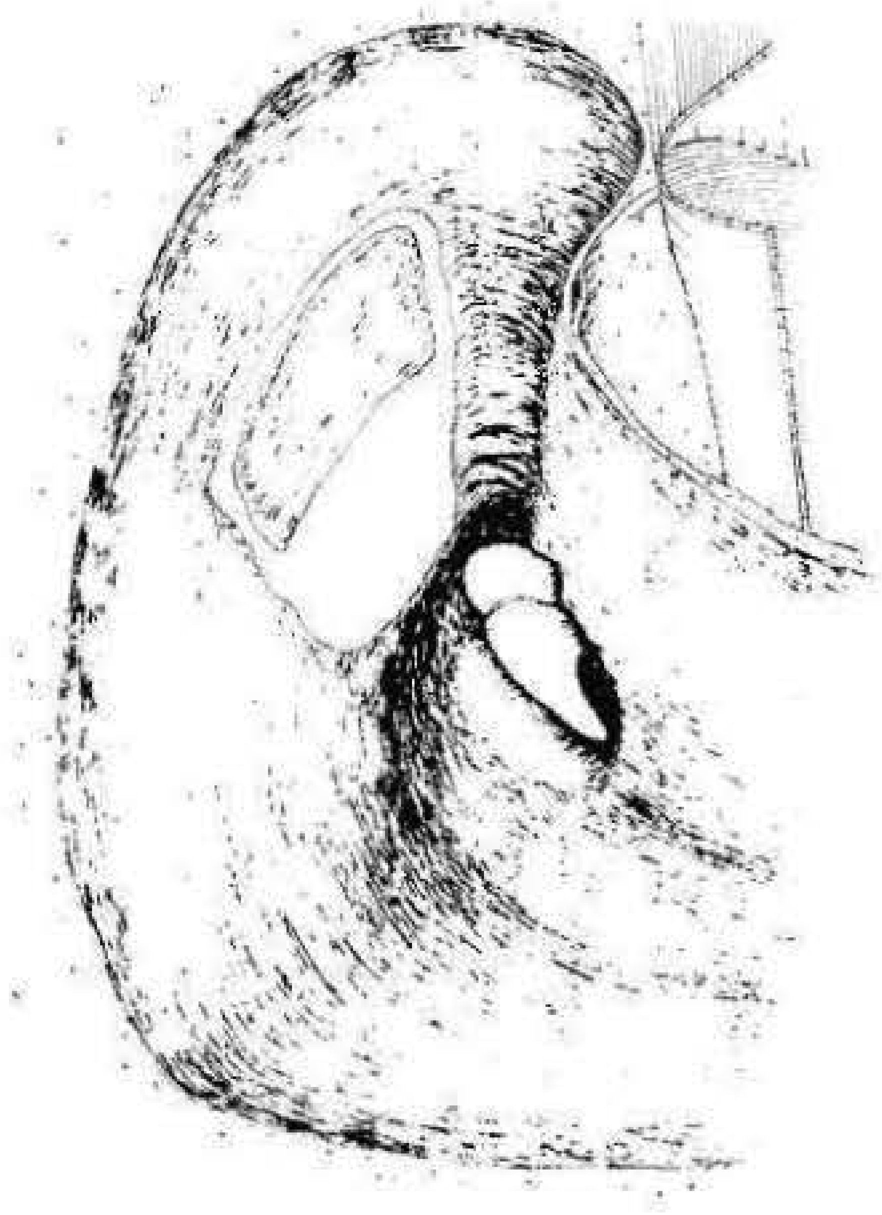


Fig. **136** **Canal wall–up mastoidectomy** after removal of an attic cholesteatoma with exposure of the dura of the tegmen antri and tegmen tympani. A mobile bony plate is attached to the dura of the mastoid tegmen

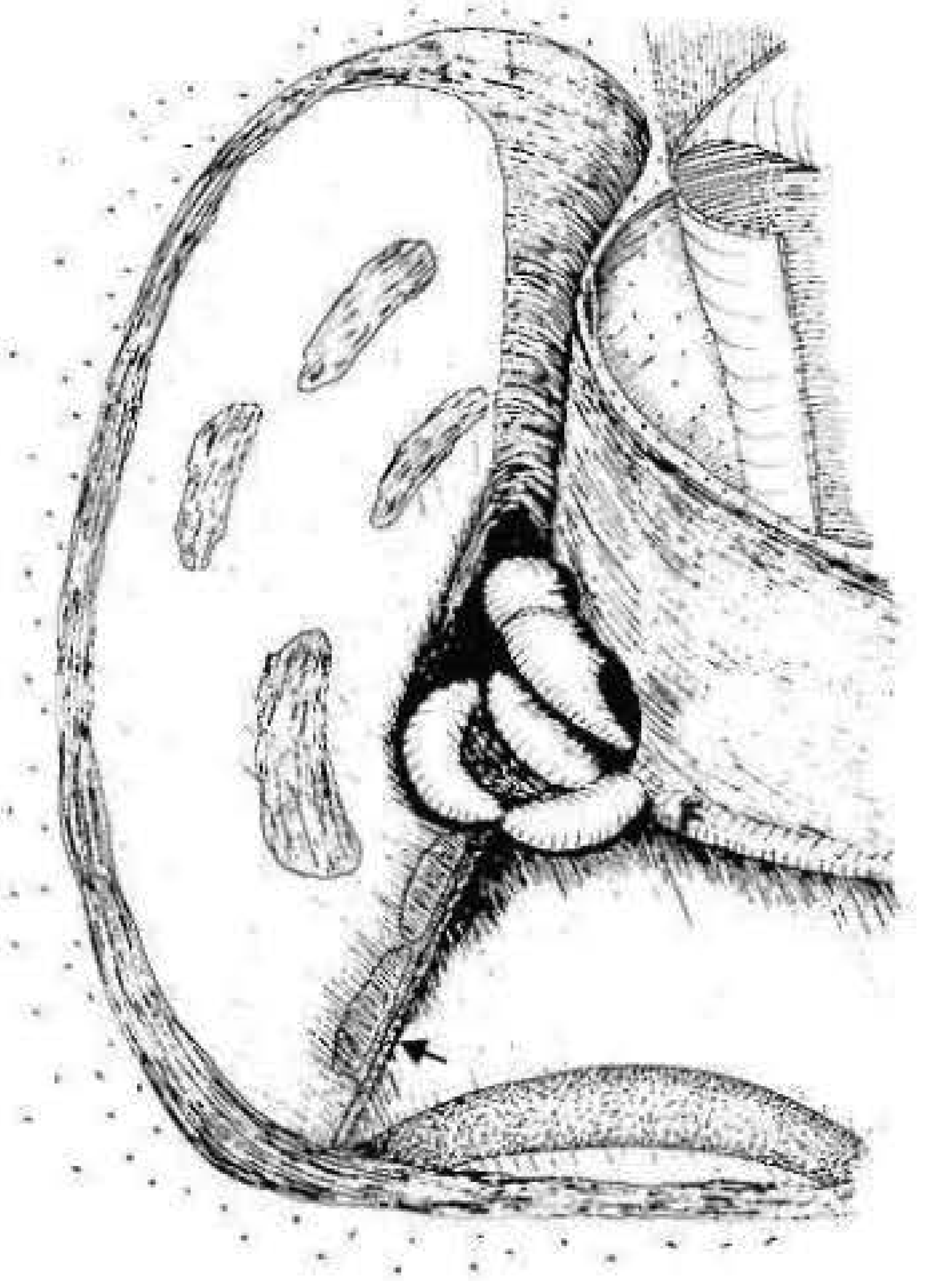


Fig. **137** **Total exposure and mobilization of the middle fossa dura**, with some islands of thin bony fragments left attached to the dura. The sinus–dura angle with the superior petrosal sinus (arrow) and the posterior fossa dura with the sigmoid sinus, are exposed before labyrinthectomy in the extended translabyrinthine approach for acoustic neuromas. The three semicircular canals are still in place, and the vertical segment of the facial nerve (F) is skeletonized

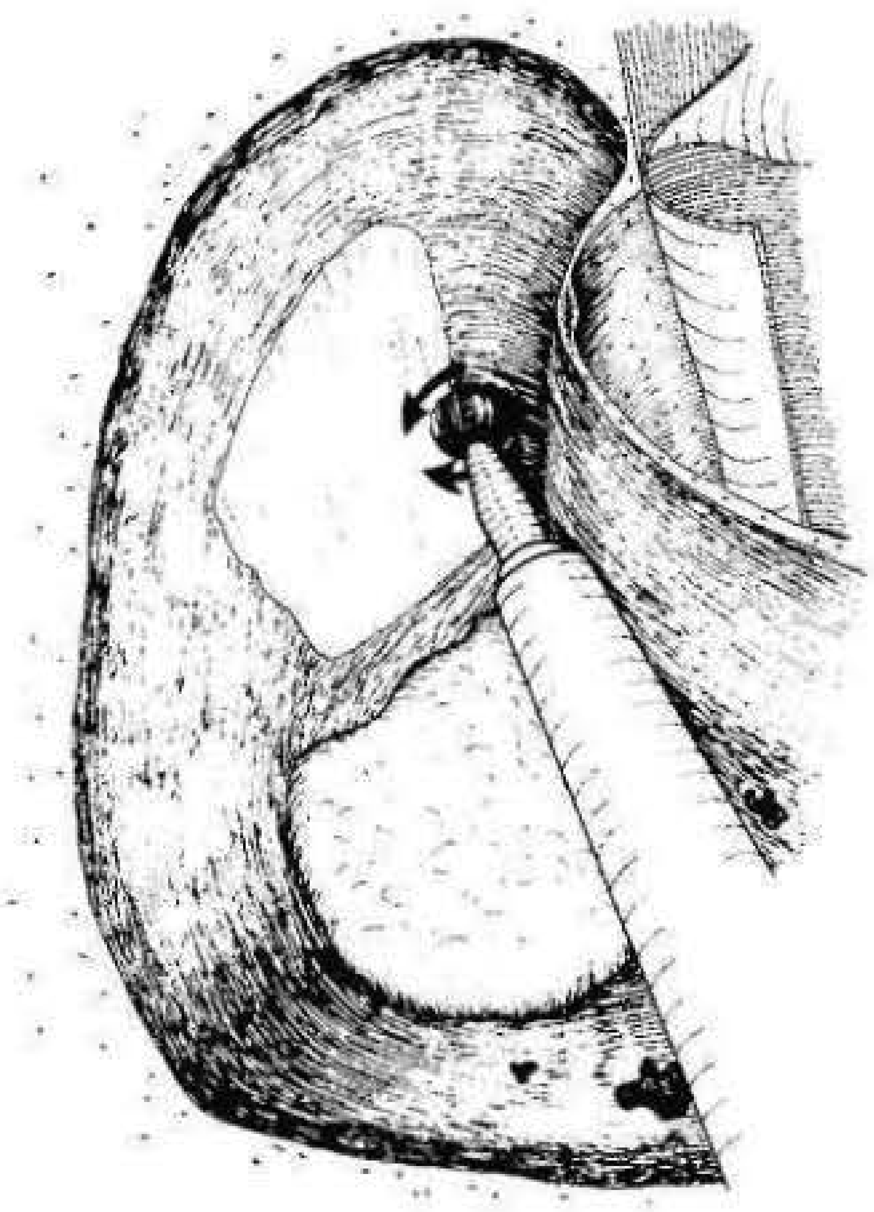


Fig. **138** **Perforation of an exposed dura** during drilling with a small cutting burr placed incorrectly on the edge of the middle fossa dura plate. There is a cholesteatoma in the attic

thine acoustic neuroma operations. This extended exposure was absolutely necessary in 400 large and giant acoustic neuromas, where mobility of the entire middle fossa dura, the superior petrosal sinus, the sigmoid sinus and the posterior fossa dura is of great benefit during surgery (Fig. **137**). It is also helpful in smaller tumors with difficult anatomy, and we have therefore made it a routine procedure to expose the entire dura. Using the largest possible diamond burr, perforation of the middle fossa dura has only occurred very rarely. The middle fossa dural plate can also be fractured with the diamond drill, and can be left attached to the dura at several places.

Damage to the Middle Fossa Dura

Damage to the dura, including perforation, can accidentally occur if a cutting burr is pressed too hard toward the tegmen mastoidei, antri, or tympani. A small burr simply passes directly through the dura.

Damage also occurs if a cutting burrr is used with excessive pressure directed onto an edge of the bone (Fig. **138**). The burr can jump off the bone through the exposed dura and into the middle fossa, with damage to the arachnoids and the surface of the temporal lobe itself.

A large cutting burr, moved gently in an anteroposterior direction over the bony plate of the mastoid tegmen, usually does no harm, but it may not be particularly efficient. It is therefore better to use a large diamond burr. A diamond burr with a high rotation speed can be as effective as a cutting burr, but much less dangerous and thus more “relaxing” to use. Using a burr of less than 2 mm in diameter will always involve a risk of perforation of the dura. A small diamond burr should be used with particular care, and especially without pressure on the dura. On the other hand, in translabyrinthine surgery, the space between the middle fossa dura plate medial to the superior petrosal sinus and the superior wall of the internal auditory meatus is narrow, and only small diamond burrs can be used here. Perforation of either the middle fossa dura or the meatal dura is common.

As well as burrs (cutting and diamond), damage to the dura can occur with other instruments, e. g., chisels or other sharp instruments perforating the dura.

When a perforation of the dura is recognized, with or without a cerebrospinal fluid leak, peroperative prophylactic intravenous penicillin is advisable, and the region should not be manipulated until the end of the operation, when the dural perforation should be closed.

Repair of Dural Defects

In acoustic neuroma surgery or other skull base surgery in which obliteration of the cavity with fatty tissue is employed, a perforation of the middle fossa dura lateral to the superior petrosal sinus is usually sealed by the fatty tissue itself, and antibiotic treatment is not necessary for this complication alone. The posterior fossa dura is opened in acoustic neuroma surgery anyway.

In middle ear surgery, the operative field is potentially infected, and a tear in the dura represents a complication that should be treated.

After ensuring that no cholesteatoma membrane has spread into the cranial fossa during the dural penetration and that no cholesteatoma is adherent to the dura or to the bony plate of the tegmen, the region should not be interfered with during the subsequent surgery. The dural defect is repaired near the end of the procedure, after the mastoidectomy has been completed and the ossiculoplasty and myringoplasty have been performed.

A small tear of the dura with no defect, resulting in spontaneous closure of any cerebrospinal fluid leak peroperatively, can be further secured with a curved bipolar diathermy forceps, ensuring permanent closure of the cerebrospinal fluid leak (Fig. **139**). In order to ensure even more secure closure, a piece of temporalis muscle fascia can be placed over the exposed dura and secured with fibrin glue.

With larger defects of the dura, closure is brought about by temporalis muscle fascia using a "triple seal" of the defect. Firstly, the defect is sealed using fibrin glue in such a way that a small amount of the glue is placed within the defect but the majority outside it, hence creating a fibrin glue collar button or cork (Fig. **140**). The sealed defect is then covered with temporalis muscle fascia, which is gently pushed under the edge of the bone all the way around the dural exposure, creating a second seal (Fig. **141**). The third seal is achieved by further gluing of the fascia to the edges to the bone (Fig. **142**). This triple seal usually requires no further covering or obliteration of the cavity.

If there is any doubt about the stability of the seal, obliteration of the cavity, with further placement of periosteum, fibrous tissue, fascia, or a pedicled subcutis–muscle flap will be required. The obliteration can be performed in both canal wall–up or canal wall–down mastoidectomy.

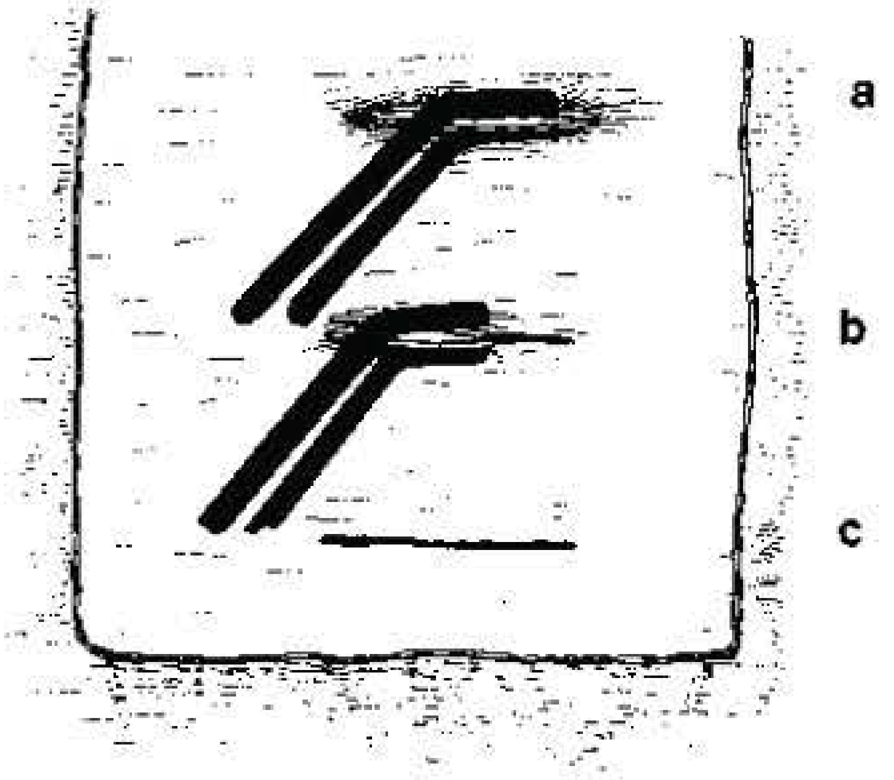


Fig. **139** **Closure of a small dural defect with bipolar coagulation.**
a A large curved bipolar pincette is placed on the small dural tear, the first coagulation gluing the two edges together.
b The final coagulation.
c The tear is solidly coagulated and closed

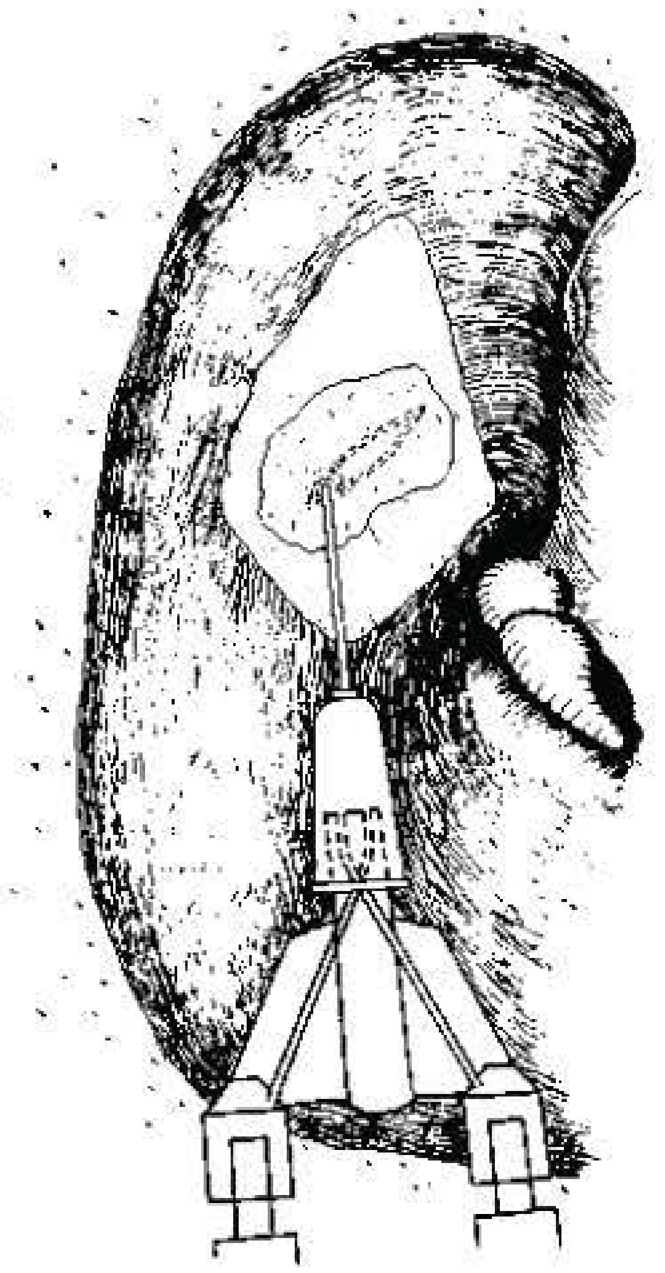


Fig. **140** **Closure of a dural defect with fibrin glue and fascia**. The dural defect (dashed line) is covered with fibrin glue placed in the defect so that it covers the defect both from inside and outside

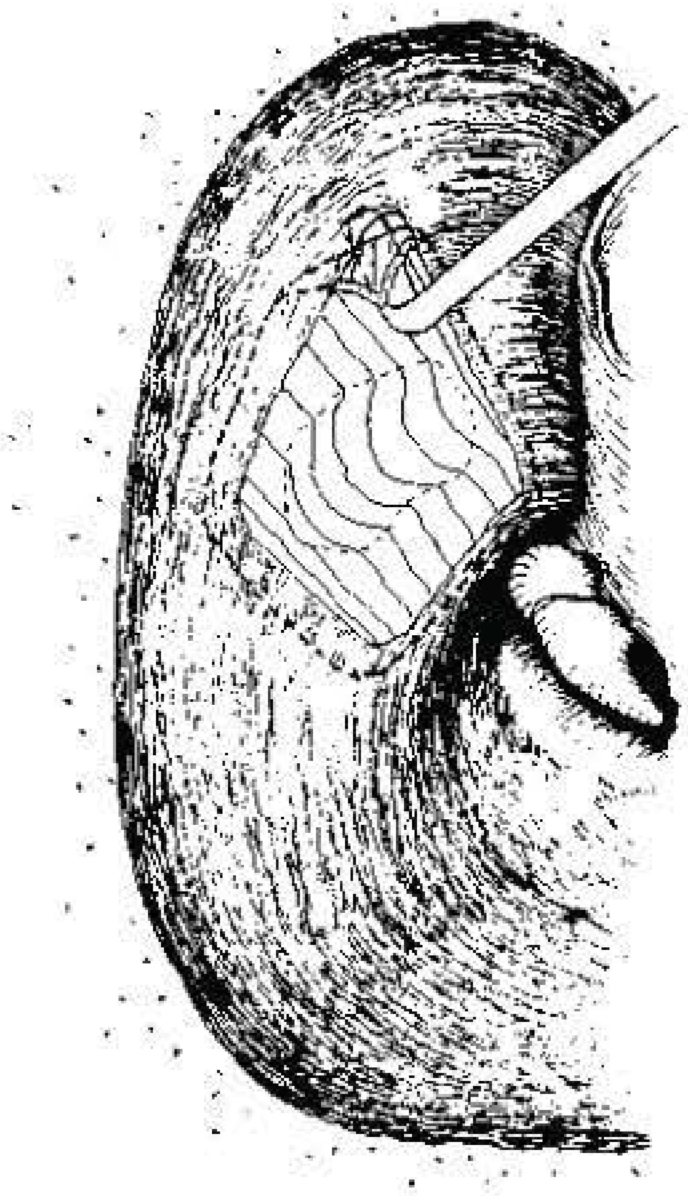


Fig. **141** A piece of the temporalis muscle fascia is placed under the bony edges, covering the entire dural exposure and the fibrin glue. After the last edge of the dura is placed under the bone with the curved elevator, further sealing is carried out around the bony edges

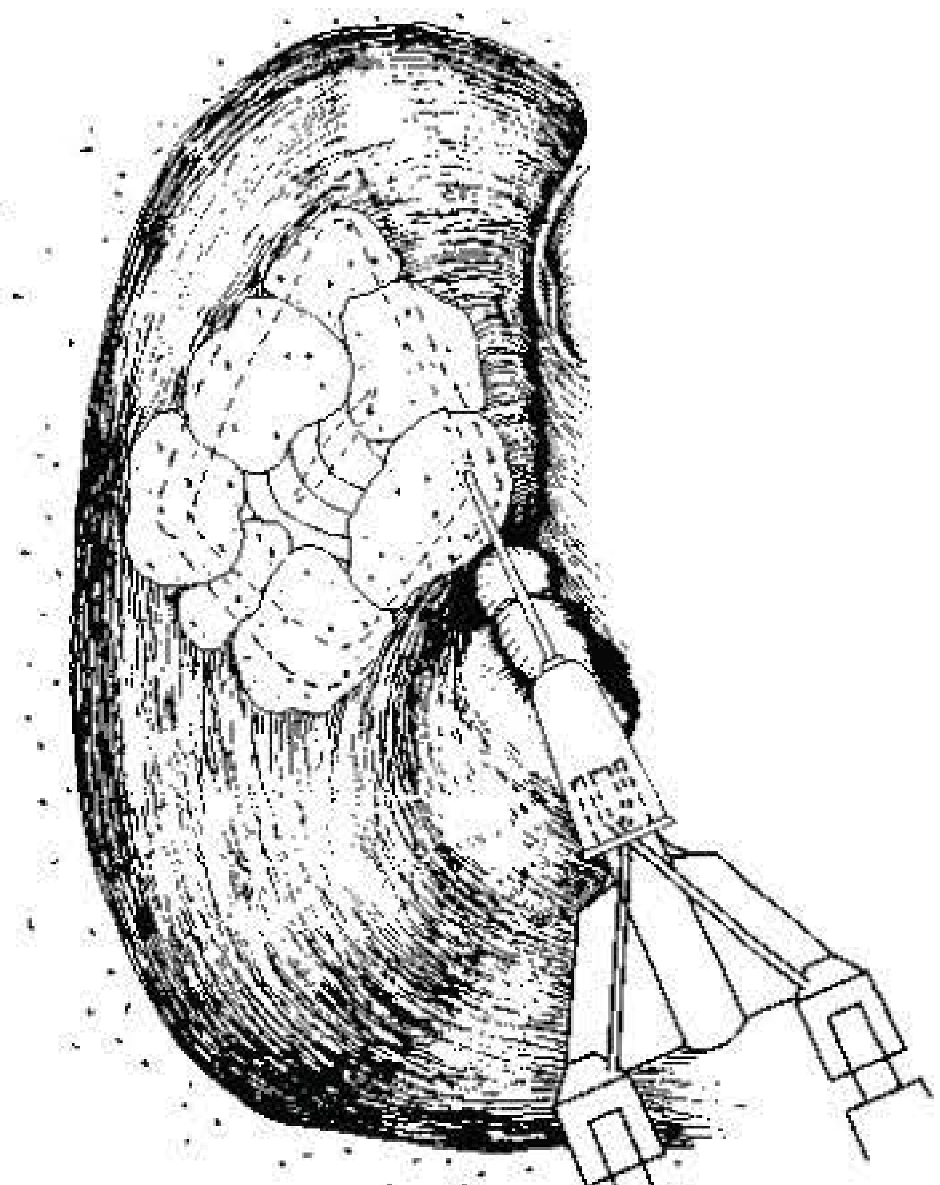


Fig. **142** The fascia is further glued to the edge of the bony defect, providing triple sealing of the defect

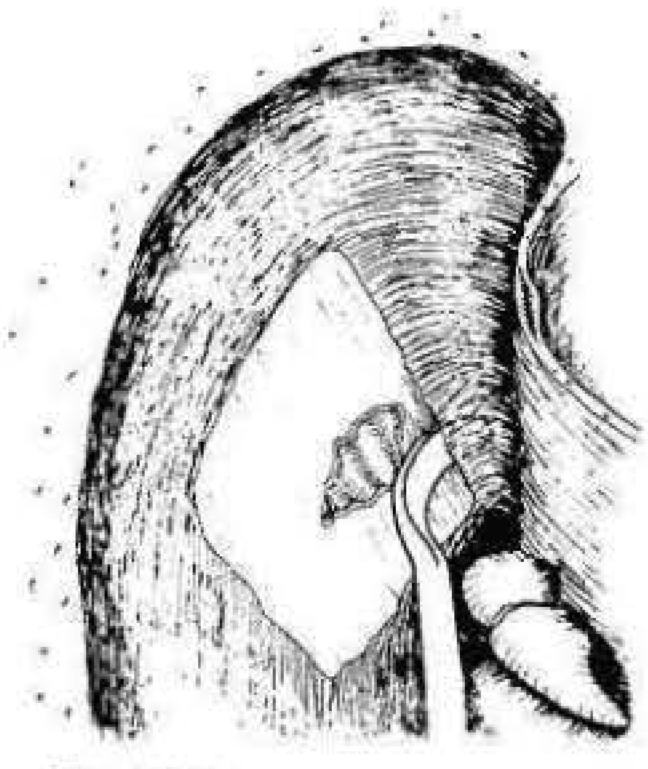


Fig. 143

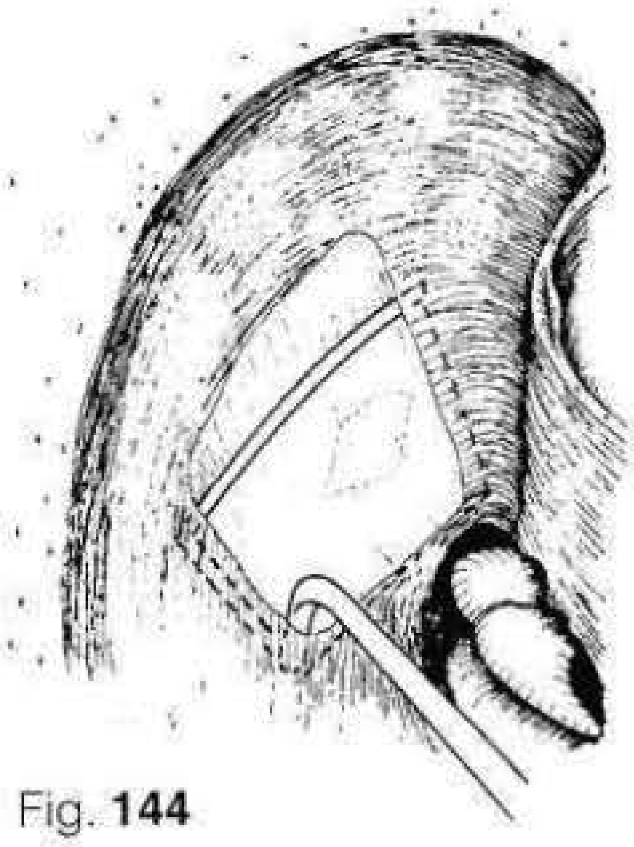


Fig. 144

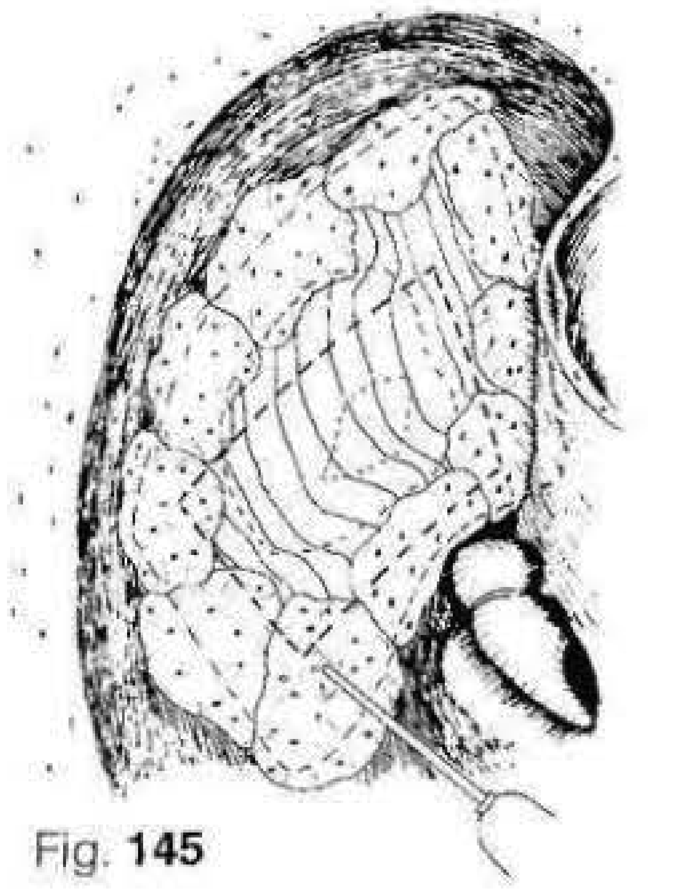


Fig. 145

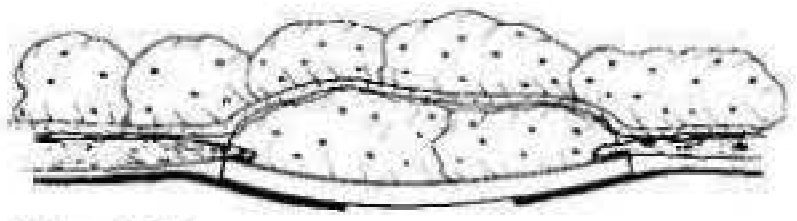


Fig. 146

Fig. **143** **Closure of a large dural defect with a cartilage plate**. The dura is elevated from the bone all the way around the exposure using a curved elevator

Fig. **144** A slightly convex conchal cartilage plate is placed between the bone and the dura, with its convex surface pointing toward the cortex

Fig. **145** The cartilage and bone edges are covered with fibrine glue, and the bone from the tegmen is covered with fascia and glued

Fig. **146** **Dural closure (side view).** The cartilage plate is placed between the dural layer and the bone, covered with fibrin glue, and again covered with fascia and fibrin glue

In larger defects of the dura resulting in cerebrospinal fluid leakage, a more substantial type of tissue than fascia should be used to cover the defect. Conchal or tragal cartilage can be placed between the dura and the bone after elevation of the dura from the bony plate (Fig. **143**). The slightly convex conchal cartilage is placed between the bone and the dura with the convex surface towards the dura. The dura is thus pushed slightly inward and stretched, providing better contact between the cartilage and the dura (Fig. **144).** The surfaces of the cartilage, the dura, and the bone edges are all covered by a layer of fibrin glue. Finally, a large piece of fascia is placed on the bone of the tegmen and secured with fibrin glue (Figs. **145, 146**), providing a triple seal. It is wise to obliterate the cavity with autogenous tissues, such as a pedicled subcutis–muscle flap, or other available tissue.

Avoidance of Dural Lesions

To avoid perforation of the middle fossa dura during drilling, the following precautions should be taken into consideration during drilling on the middle fossa dura plate:

1. Obtain extensive lateral exposure through a sufficiently wide approach to the mastoid process (Fig. **147**).
2. Use a large burr whenever possible. It is best to use the largest cutting burr along the middle fossa dural plate.
3. Avoid running the burr across the bone edge.
4. Use light pressure intermittently.

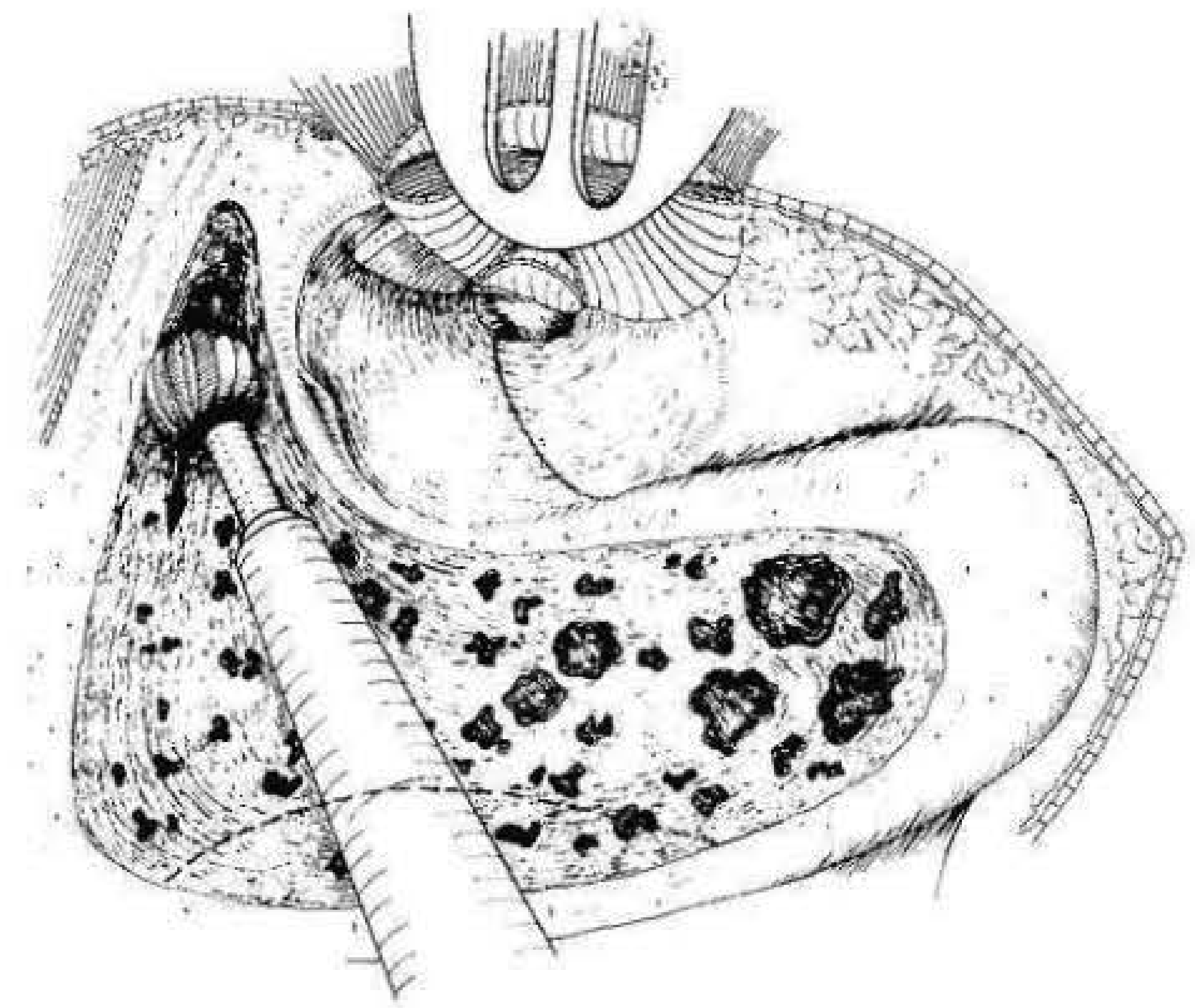


Fig. **147** **Skeletonizing the mastoid tegmen** in a canal wall–up mastoidectomy in an ear with a well-pneumatized mastoid process. The cortex has been widely removed. Using a large cutting burr, the tegmental cells are exenterated by moving the burr in a posterior direction. The ear canal is exposed by elevating the skin flaps and protecting them with the protective blade of the House–Sheehy retractor. The tympanosguamous suture is visible superiorly and the tympanomastoid suture inferiorly in the ear canal

5. Avoid continuous pressure on the dural plate (Fig. **147**).
6. Drill with a "light hand," holding the handpiece like a pen.
7. Use the side of the burr as a cutting edge, rather than its head.
8. Proceed slowly along the middle fossa dural plate (Fig. **148**), removing the bridges between air cells where present.
9. Sometimes large air cells extending up to the mastoid tegmen are present, and the bony plate covering the dura at these points may be very thin. It is therefore best to use intermittent pressure, keeping the middle fossa dural plate in view constantly.
10. Use constant irrigation during drilling in order to maintain a good view of the bone at all times.
11. Don't use the burr blindly in small holes; keep the field as wide as possible.
12. If you are in doubt as to the level of the mastoid tegmen, expose the dura laterally (Figs. **129**, **130**).
13. After the tegmental cells have been removed and the bony dural plate has been located, it is safest to change to a large diamond burr and polish the mastoid tegmen as far as to the Körner's septum.

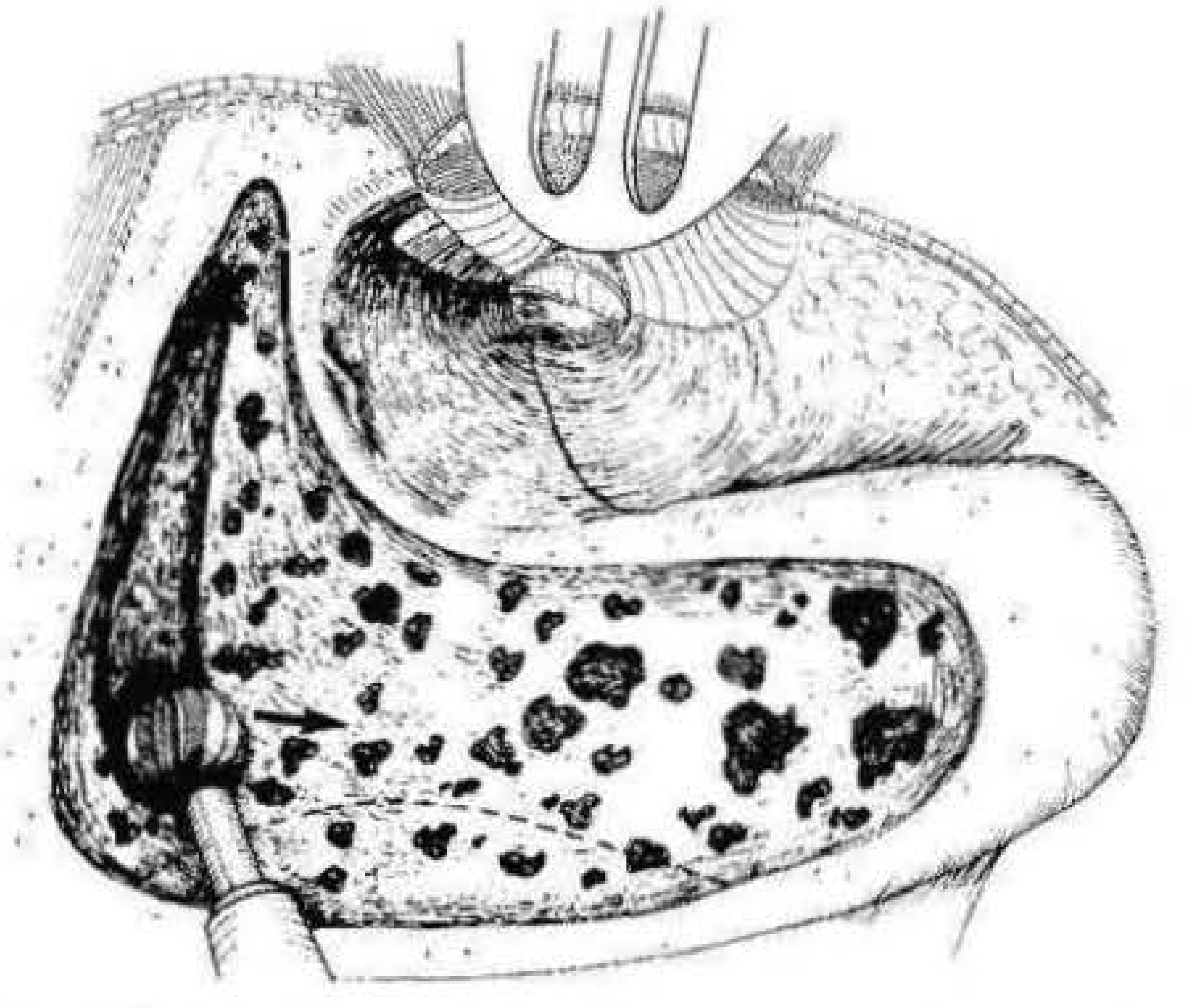


Fig. **148** The tegmental cells are removed, exposing the bony plate of the mastoid tegmen. From the sinodural angle, the cutting burr is moved in an inferior direction to exenterate the perisinusal cells

Exposure of the Sigmoid Sinus

In middle ear surgery, deliberate exposure of the sigmoid sinus is seldom necessary. Usually, good skeletonization is enough to provide an adequate view of the mastoid process in order to remove cholesteatoma or other pathology. With an *anteriorly positioned* sinus and a very short distance between the posterior border of the bony external auditory canal and the anterior sinus wall, partial, or sometimes even total, displacement of the most prominent part of the sinus is necessary in order to remove cholesteatoma medial to the sinus. Before such displacement, exposure of the sinus is necessary.

In skull base surgery, total exposure of the sinus is routine for most approaches. In our extended translabyrinthine approach for large and giant acoustic neuroma tumors (Tos and Thomsen 1991), total exposure of the sigmoid sinus from the transverse sinus to the jugular bulb is a routine procedure. The cortical bone is also removed posterior to the sinus, in order to push the sinus posteriorly. In translabyrinthine surgery for small acoustic neuromas, we always thoroughly skeletonize the sigmoid sinus, even if it is posteriorly positioned. In all other cases, the sinus is totally exposed.

In endolymphatic sac surgery, exposure of the sinus is a routine procedure, since the sac is more easily and safely found by exposing and posteriorly displacing the sigmoid sinus. A knowledge of the methods of sinus exposure and associated complications can make the ear surgeon more confident when performing mastoidectomy, allowing for faster surgery in this region.

After extensive removal of the cortical bone and wide exposure of the lateral aspect of the mastoid process (Fig. **147**), the mastoid tegmen and the sinodural angle are identified (Fig. **148**). Exenteration of the air cells anterior and lateral to the likely position of the sigmoid sinus is started in a superoinferior direction (Fig. **149**). With a large cutting burr, light and intermittent pressure is applied with constant irrigation, allowing visualization of a blue discoloring of the bone. As long as the bony septa of air cells are present without the blue color of the underlying bone, drilling can continue with a large cutting burr (Fig. **150**), still moving it in a superoinferior direction along the course of the sigmoid sinus. The lateral sinus cells, if present, are removed, resulting in smooth bone appearing over the entire lateral and anterior surfaces of the sinus (Fig. **150**).

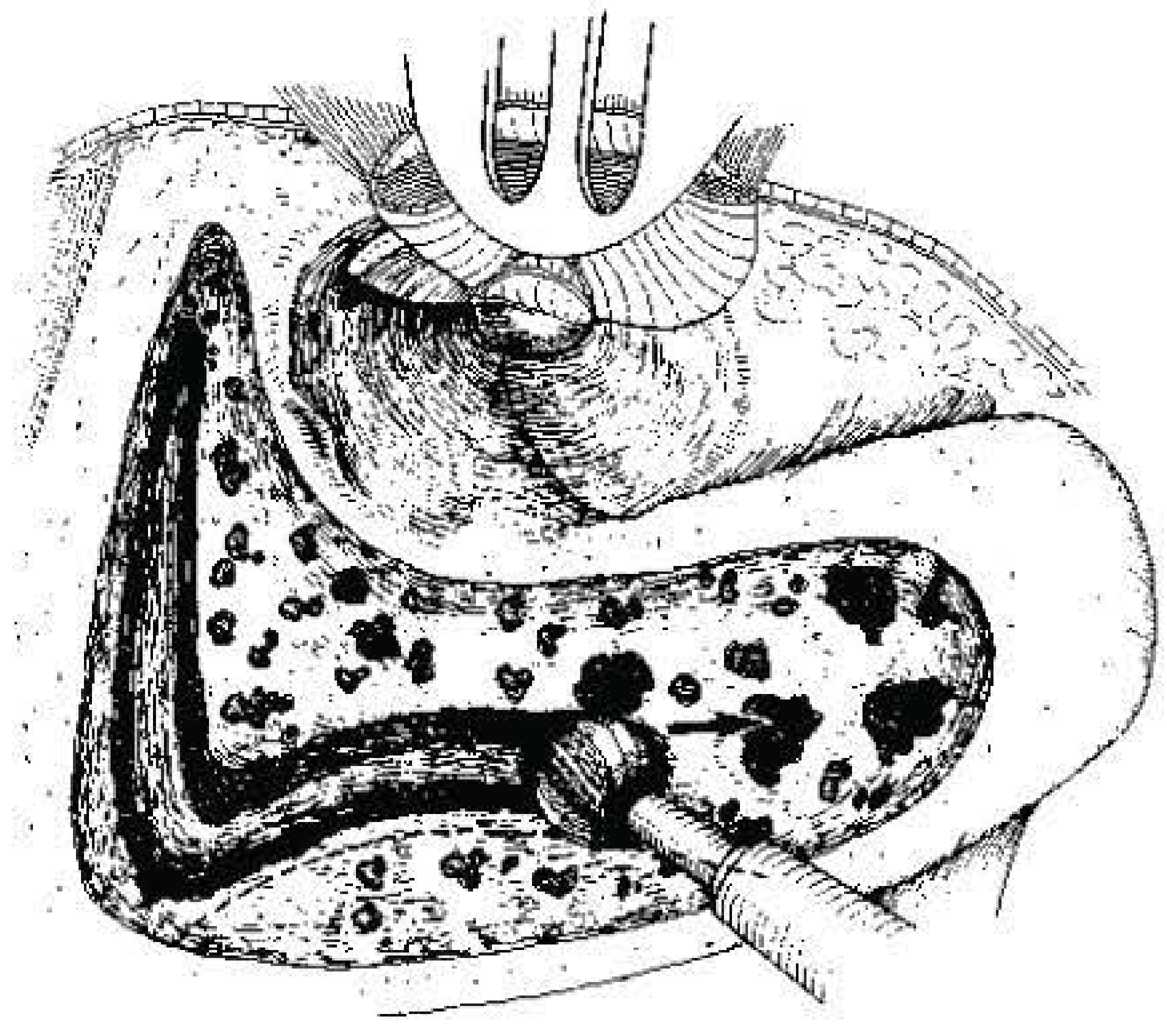


Fig. **149** The perisinusal cells are exenterated by moving the large cutting burr in the superoinferior direction, carefully observing the bluish color of the bone covering the sinus

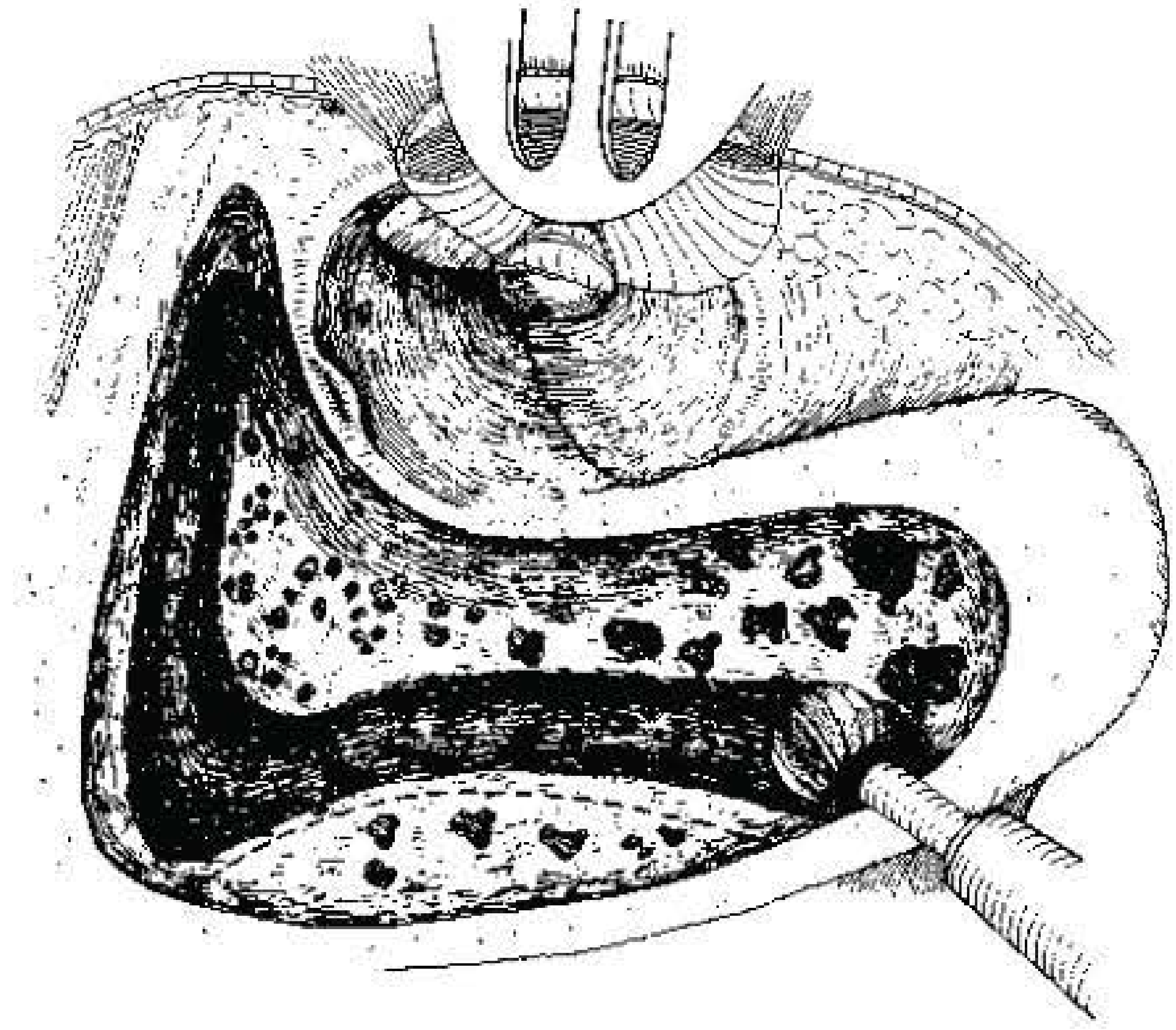


Fig. **150** The burr is moved further inferiorly, exenterating the apical air cells

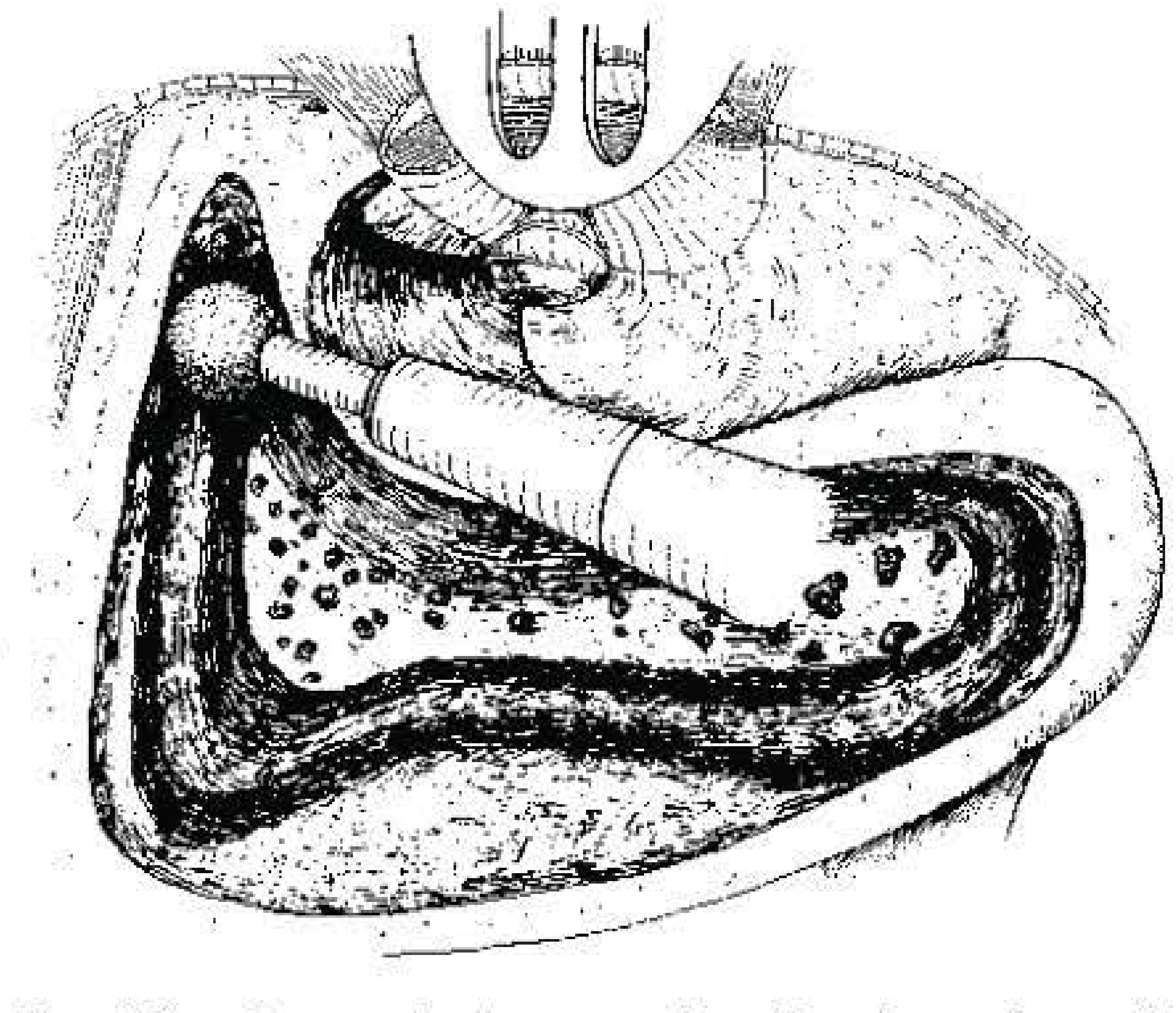


Fig. **151** By gradually removing the bone from the middle fossa dura plate, the sigmoid sinus, and the posterior fossa dura plate using a large diamond burr, the air cells are exenterated, exposing Körner's septum

Further skeletonization of the sinus depends on the situation. If the space created is large enough to remove disease medial to the sigmoid sinus, the antrum, and the anterior attic, no further skeletonization is needed. The surface of the sinus is polished with the largest diamond burr, and after further polishing of the middle fossa dura plate down to Körner's septum and of the posterior canal wall, the cavity is gradually enlarged (Fig. **151**).

If the space created is narrow, as it is in an anteriorly positioned sinus (Fig. **152**), and if the pathology requires the displacement of the sigmoid sinus, the sinus must be exposed by careful removal of bone (Figs. **153, 154**) and protected by the suction tube during the further removal of underlying bone and subsequent dissection of the cholesteatoma (Fig. **155**).

There are several methods of exposing the sigmoid sinus: 1) creation of "Bill's island," 2) the eggshell method, and 3) total bone removal or total exposure of the sinus.

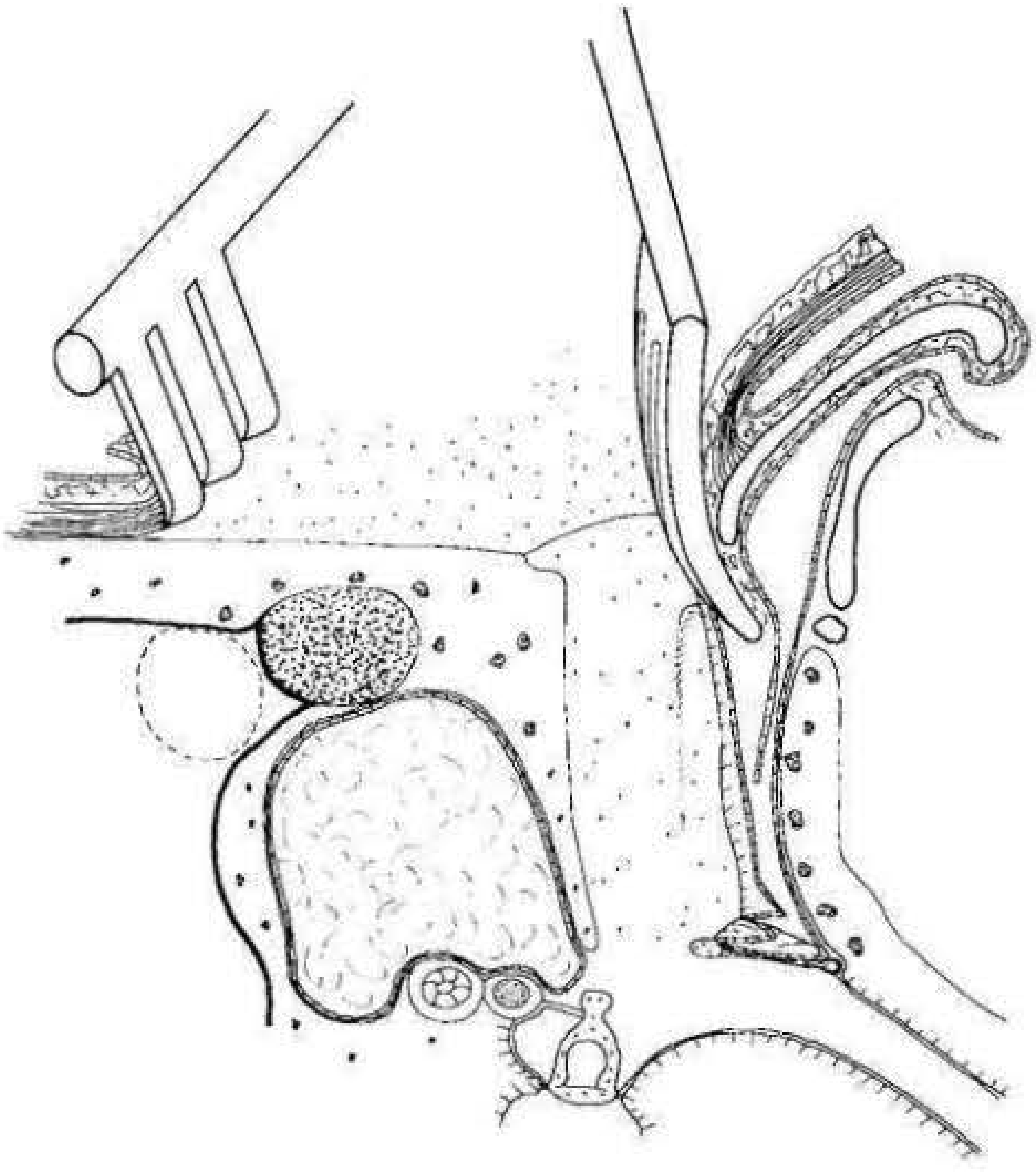


Fig. **152** **Perspective side view of an anteriorly positioned sigmoid sinus** in a case of attic cholesteatoma, concealed medial to the sinus, which cannot safely be removed without displacement of the sinus posteriorly, toward the dashed line

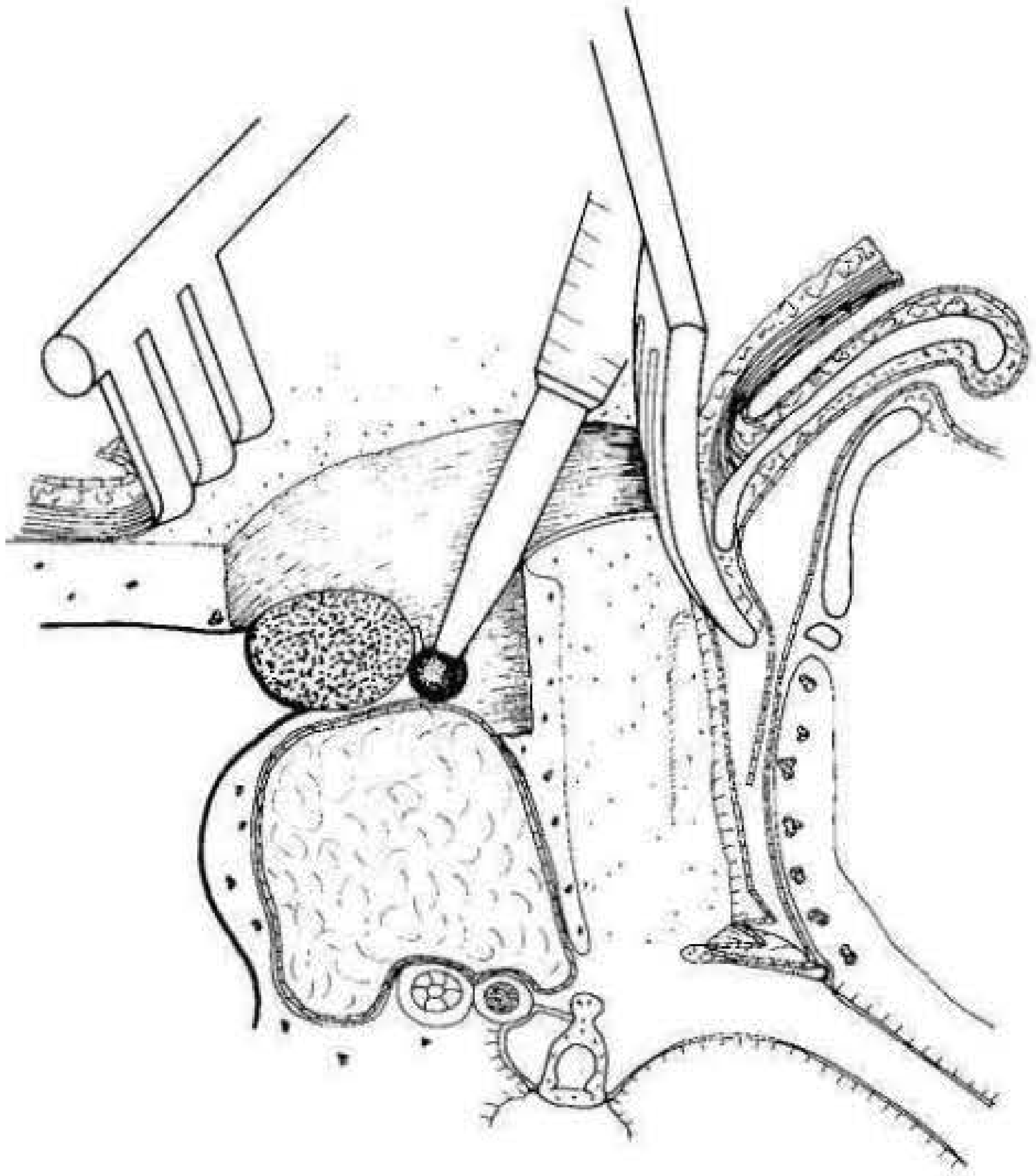


Fig. **153** The cortical bone from the sigmoid sinus is drilled away, leaving the posterior bony wall of the ear canal intact. The anterior or medial surfaces of the bony wall of the sinus are exposed using a diamond drill

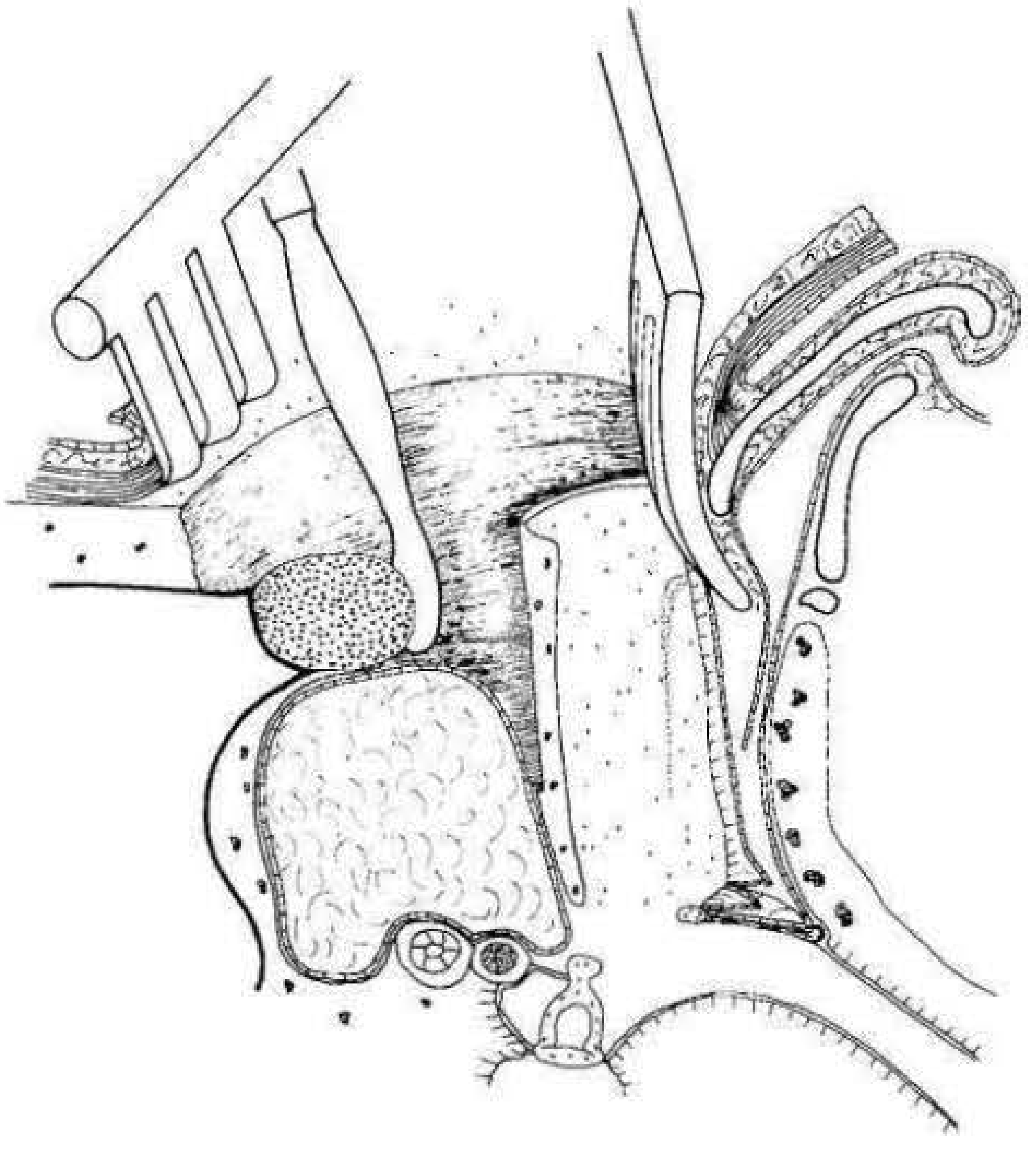


Fig. **154** The totally exposed sigmoid sinus can be gently pushed posteriorly, and the drilling of its medial wall can continue

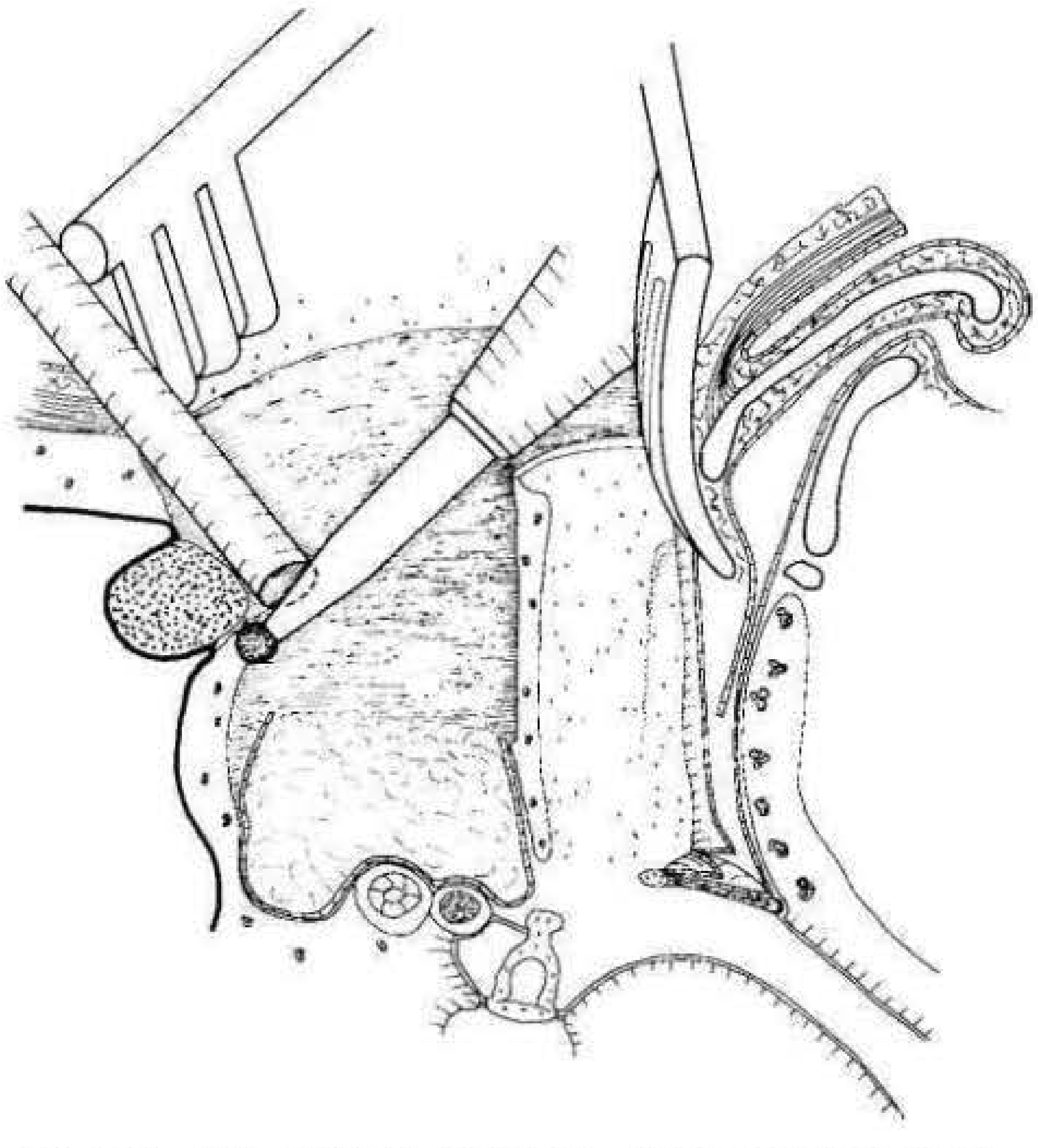


Fig. **155** The sinus is exposed, displaced posteriorly, and protected by the suction tube during further drilling of its medial wall and during dissection of the cholesteatoma membrane from the bone. The lateral part of the cholesteatoma has already been removed

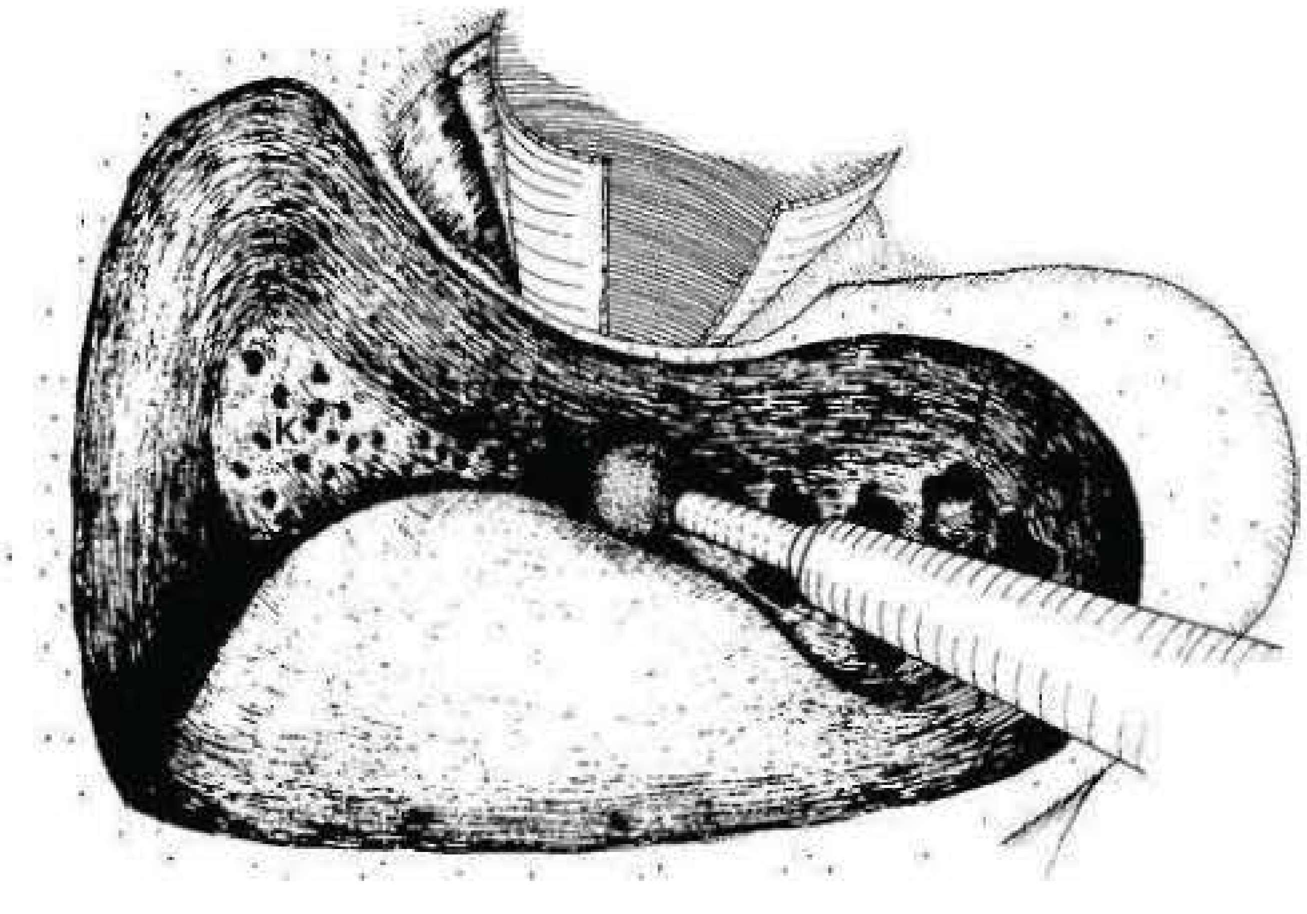


Fig. **156** Formation of Bill's island. The sigmoid sinus is positioned anteriorly, and a canal wall–up mastoidectomy technique is being employed after exenteration of the lateral mastoid air cells. The sinus has been skeletonized. K: Körner's septum

Bill's Island Method

When performing translabyrinthine surgery, Bill House drilled an island of bone over the most prominent part of the sigmoid sinus, mobilizing and then pushing it posteriorly (House and Luetje 1979). First, the sinus bone should be skeletonized using a large diamond burr to a thickness of 0.5 mm of bone (Fig. **156**). Then a groove is carefully drilled circumferentially around the most prominent part of the bone with a 1-mm diamond burr, exposing a strip of sinus all the way around (Fig. **157**). The island of bone is then fractured and pushed posteriorly, and can be held in this position by a suction tube. The anterior part of the bone can then be safely drilled using a large diamond burr (Fig. **158**). The bone from the superior part of the sinus prominence is then drilled (Fig. **159**). Finally, the inferior part of the bony prominence is drilled whilst exposing the sinus and pushing it posteriorly (Fig. **160**).

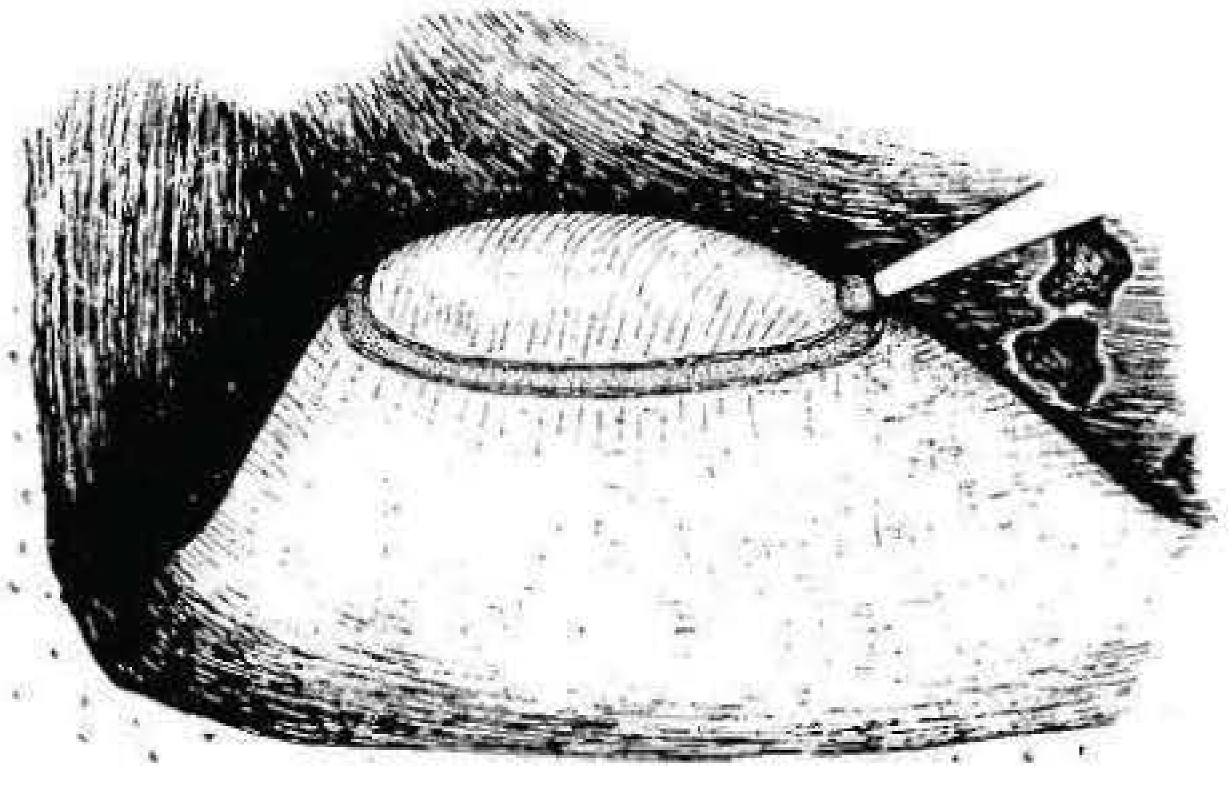


Fig. **157** A groove is drilled around the prominent part of the sinus using a small diamond burr, creating a Bill's island

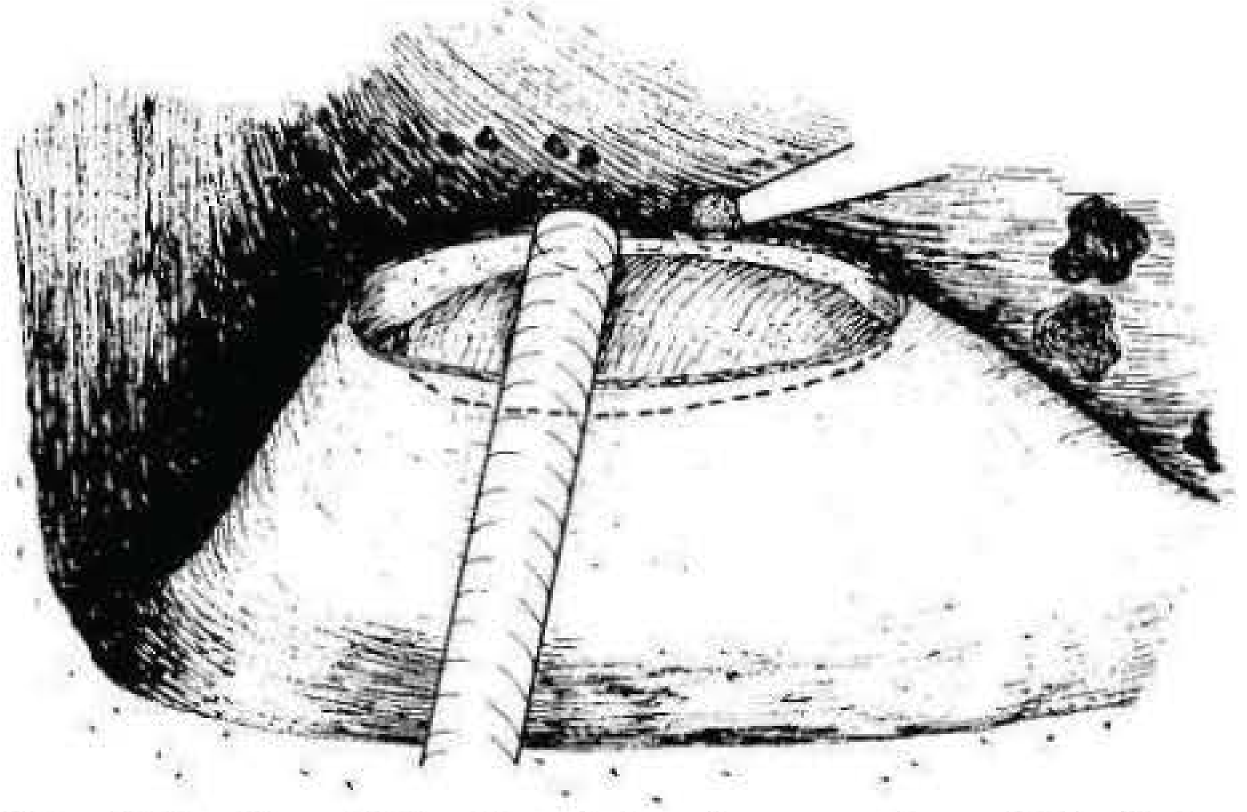


Fig. **158** The Bill's island is depressed and held in place by a suction tube. The bone situated anteriorly to the sinus, forming the edge between the sinus and the dura, can now be removed by further drilling with a large diamond drill

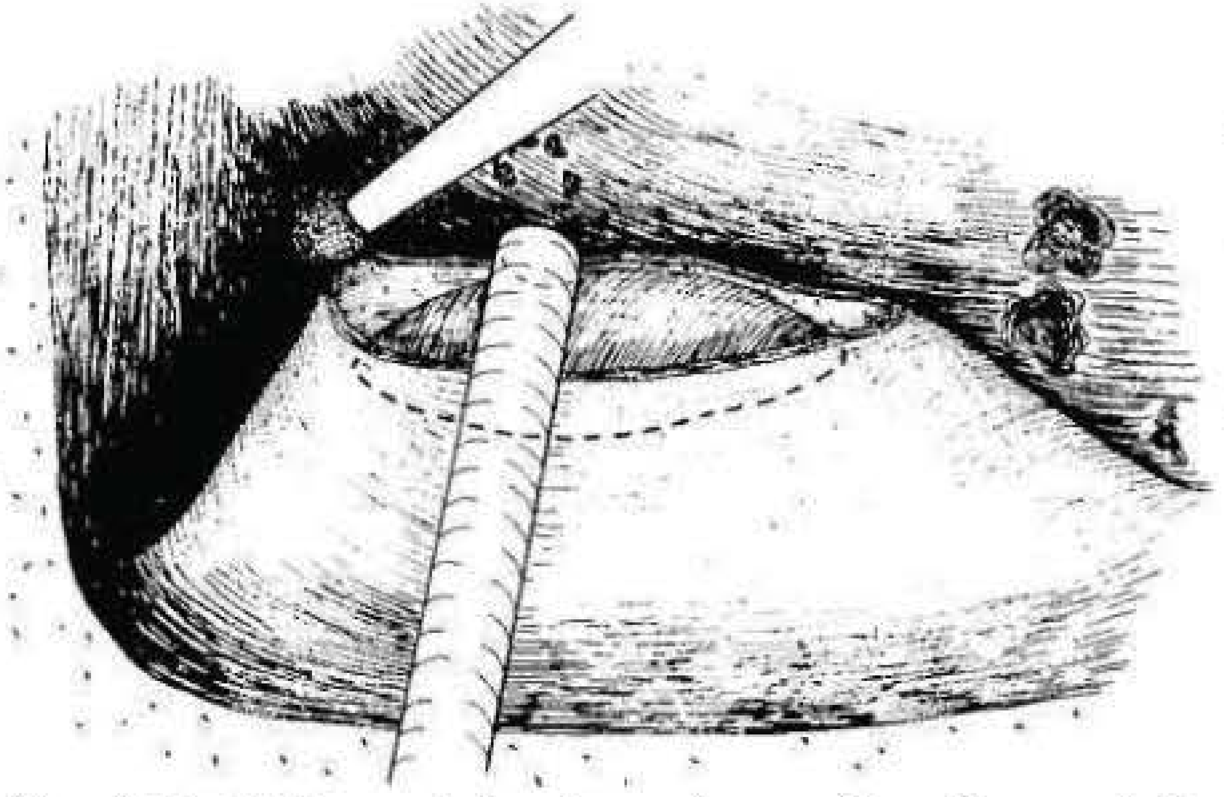


Fig. **159** Drilling of the bone is continued superiorly along Bill's island, exposing the superior part of the sigmoid sinus

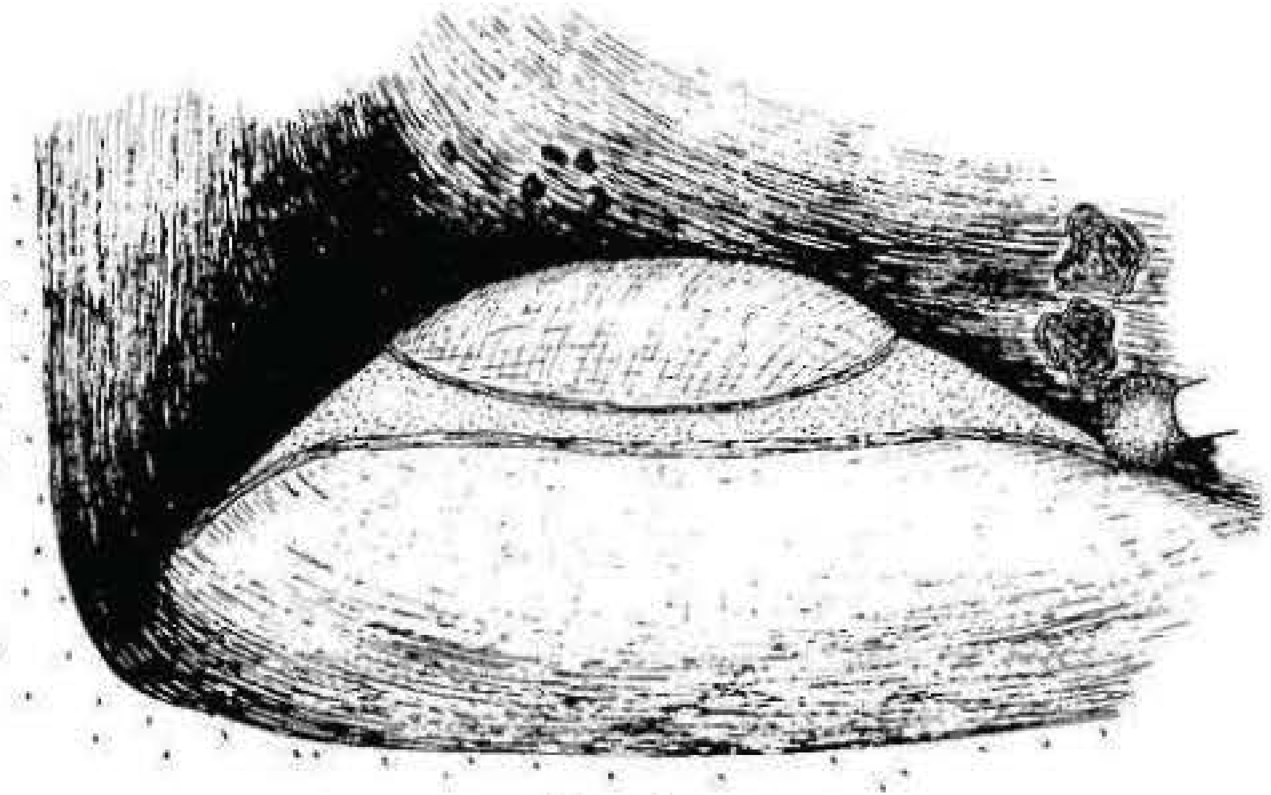


Fig. **160** The sigmoid sinus is now exposed, and the Bill's island is still attached to the sinus wall

This method is not easy to perform. The burr used for drilling out the island should be small, and there is some danger to the sinus wall. The idea of the island is to protect the sinus during later manipulation, but the island can tilt on its edge, and the edge can then damage the sinus wall.

The Eggshell Method

The author almost exclusively employs this method, the principle being to drill the entire sinus wall as thin as possible with a large diamond burr before fracturing it. This is achieved by continuous drilling of the bone covering the sinus, skeletonizing it to such a degree that the periosteum and the thin bony shell are fractured into several small pieces during the drilling with a large diamond burr gradually. These small islands of thin bone remain attached to the sinus (Fig. **161**). The sigmoid sinus wall is now compressible, either using a suction tube or a Freer's rougine (Fig. **162**). By pushing the superior part of the sinus back using the suction tube, the bone lying medial to the sinus can now be safely drilled, still using the eggshell method (Fig. **163**). Drilling continues along the sinus inferiorly (Fig. **164**), still pushing the compressible sinus back from the bone with the suction tube. After completing the skeletonization of the sinus using the eggshell method, the sinus may be totally exposed in some parts because some of the islands of bone become detached from the sinus, but the majority of the compressible thin bone covering the sinus will still protect it (Fig. **165**).

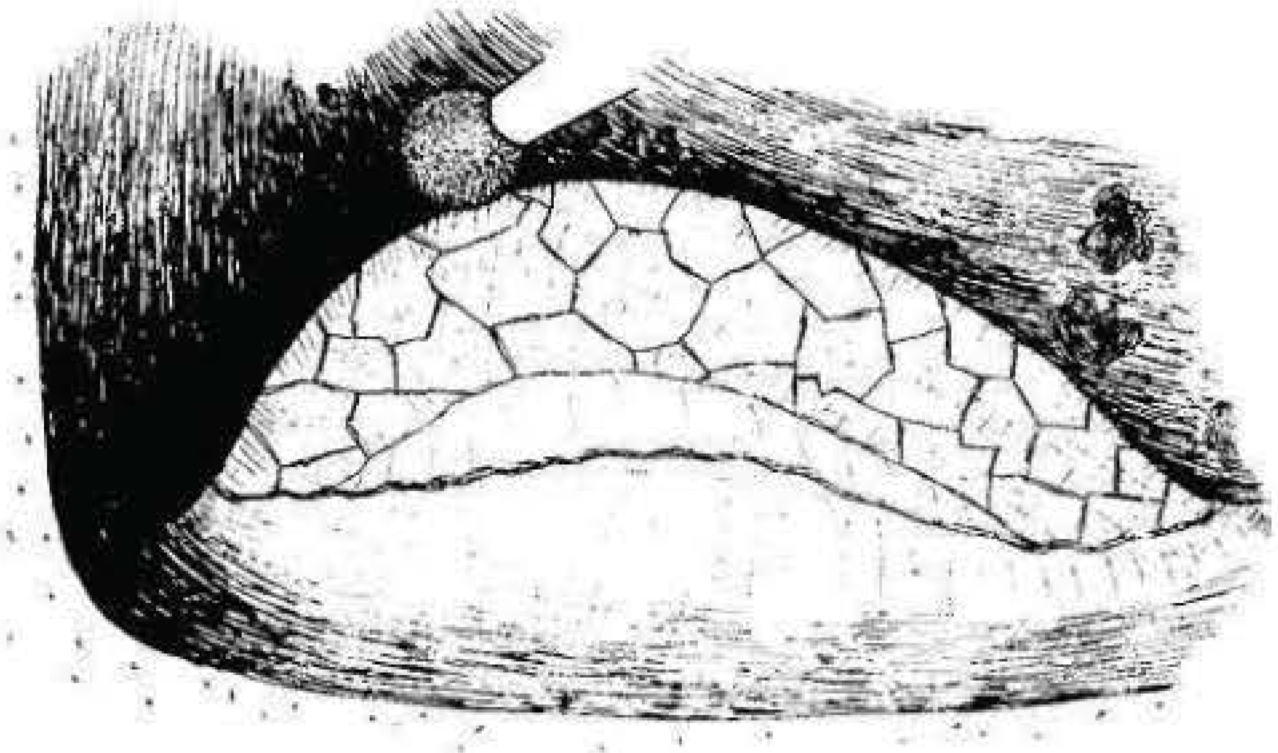


Fig. **161** **The eggshell method of skeletonizing the sigmoid sinus.** Using a large diamond drill, the bone covering the sigmoid sinus is continuously drilled thin, and finally fractured, forming many small bony islands with an eggshell appearance

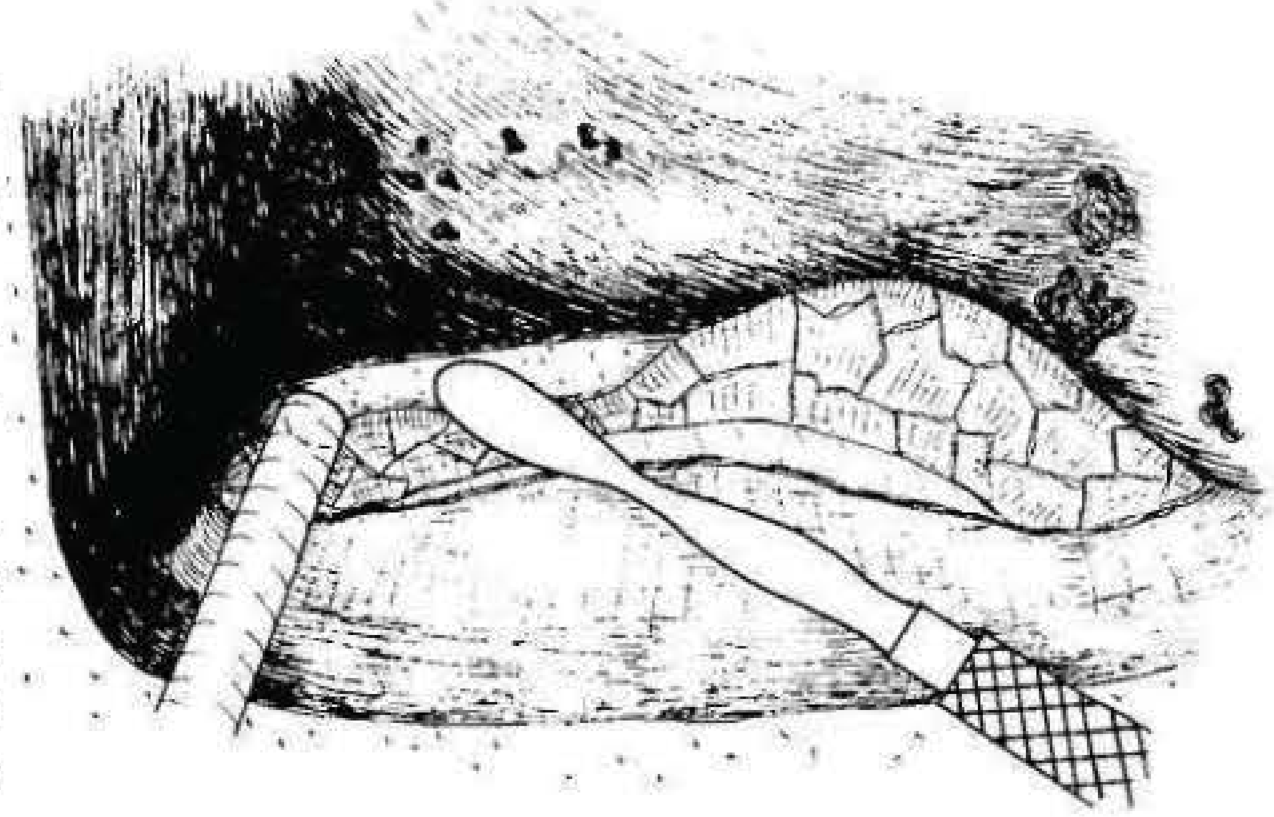


Fig. **162** The sinus is now compressible with a suction tube or a Freer's rougine, and the bone around the sinus can be drilled away

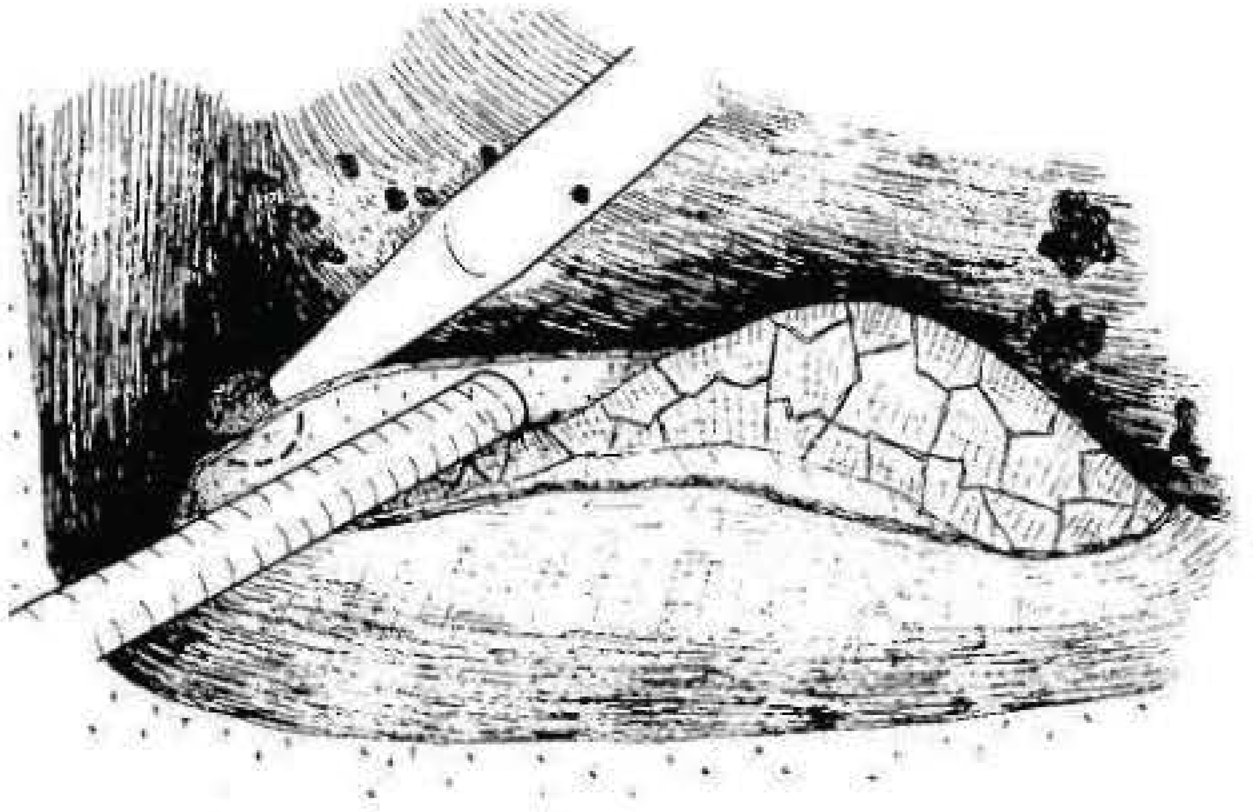


Fig. **163** The bone is drilled thin superiorly. The sinus is protected by a suction tube

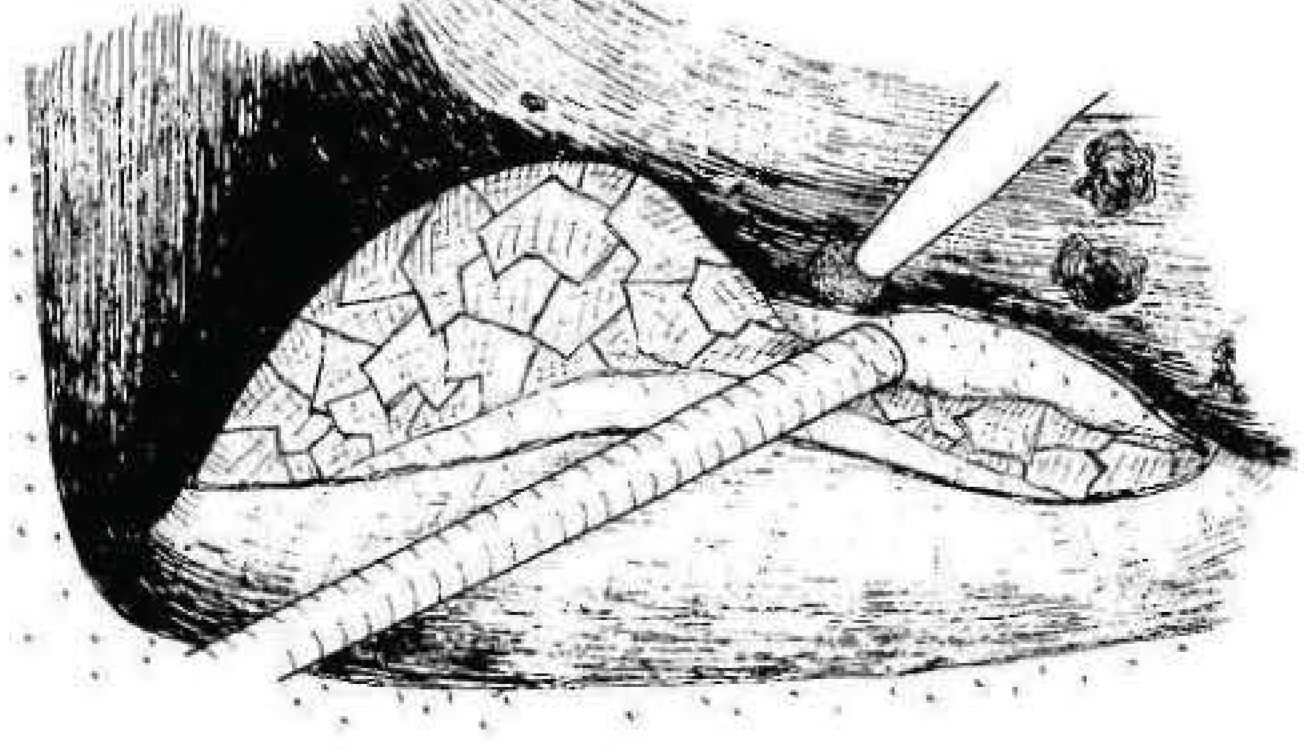


Fig. **164** The bone is removed inferiorly around the sigmoid sinus

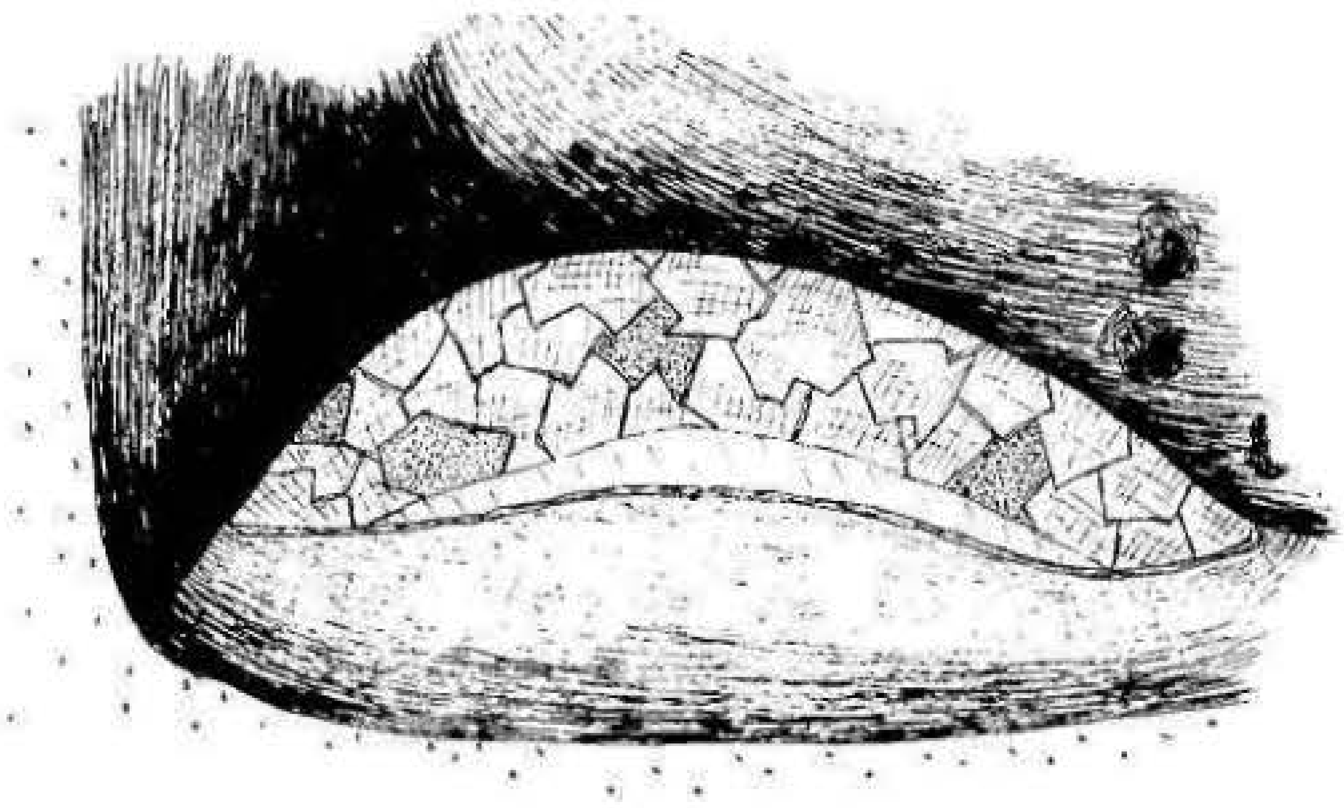


Fig. **165** The entire sinus is still covered with thin bony islands forming an eggshell, except for a few places where the bony islands have loosened and the sigmoid sinus is exposed

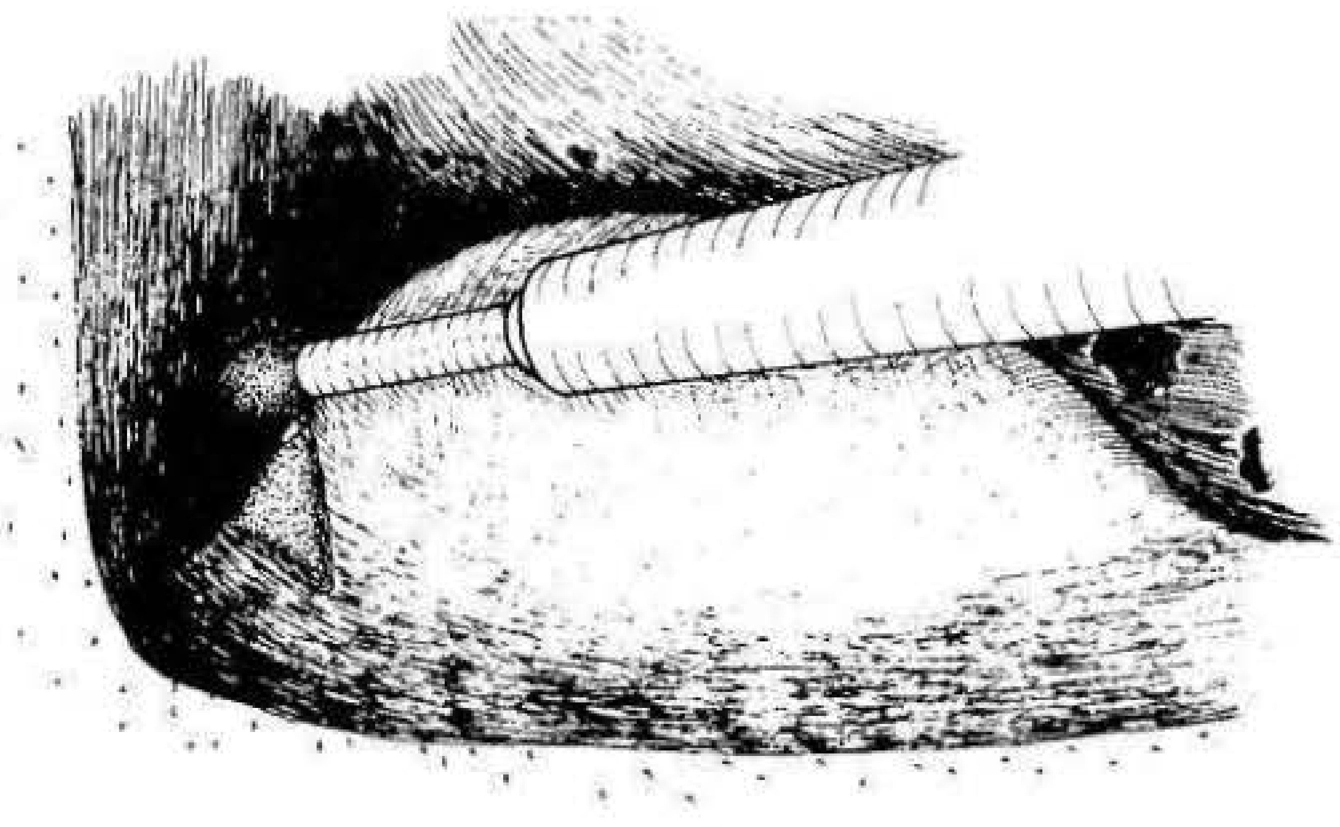


Fig. **166** **Total exposure of the sigmoid sinus**. Exposure of the superior part of the sinus is seen here

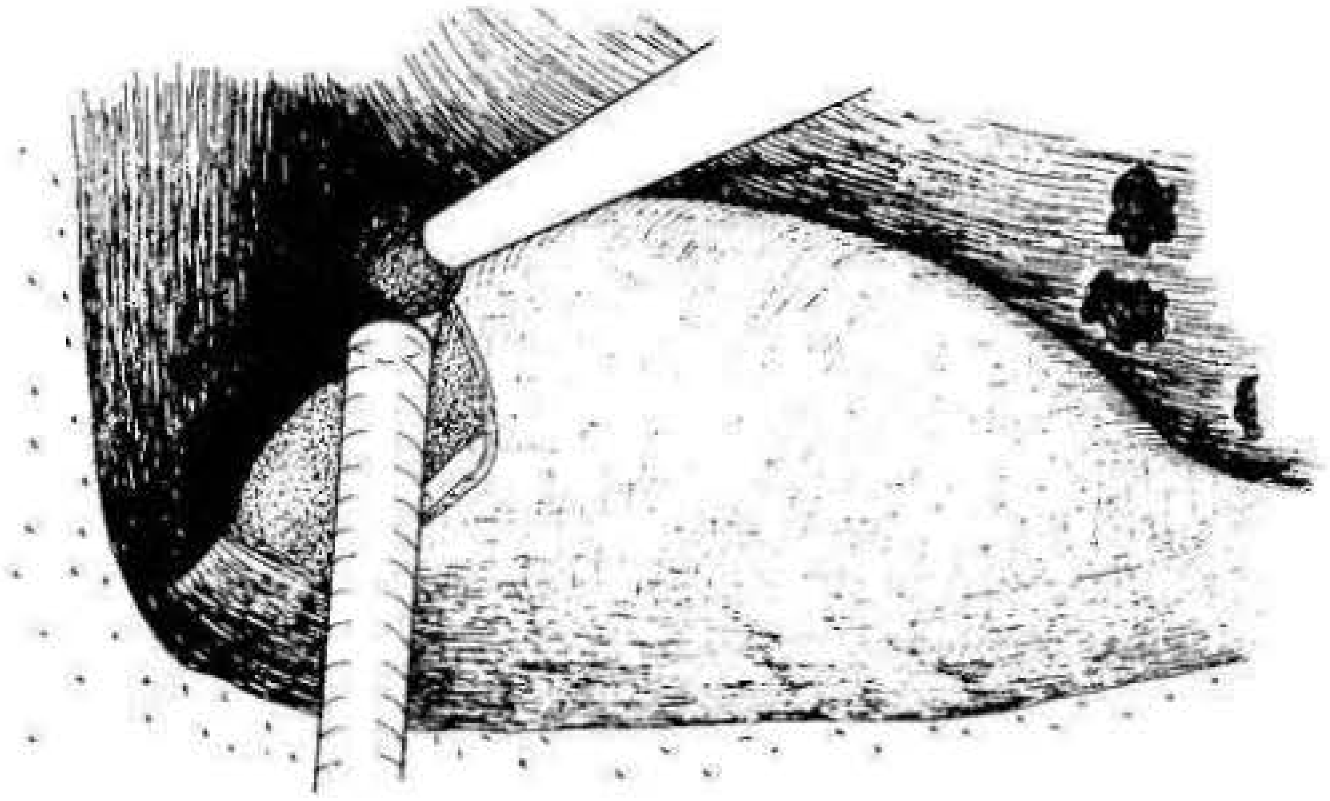


Fig. **167** The upper part of the sinus is protected by a suction tube, and the bony edges are drilled away

Total Exposure of the Sigmoid Sinus

The sigmoid sinus can be totally exposed by removing all the bone from its walls. This is necessary if the sinus becomes exposed in one part during drilling and thus vulnerable. In such cases, it is safer to continue with total exposure of the sinus than to use the Bill's island method or the eggshell method (Fig. **166**). With a thick suction tube, the exposed part of the sinus is gently pushed posteromedially. The bony edge is now freed and can be safely drilled away using a large diamond burr (Figs. **167, 168**). This maneuver is gradually continued along the entire sinus, starting superiorly and continuing in an inferior direction (Fig. **169**). The principle of this method is the displacement and protection of the sinus, using **a** suction tube to avoid contact between the drill and the sinus wall (Figs. **170, 171**).

In mastoid surgery for chronic otitis media, complete exposure of the sigmoid sinus is very seldom necessary. Such exposure is only really necessary with an extremely anteriorly positioned sigmoid sinus combined with a large cholesteatoma approached by the retroauricular incision and the transcortical route. Sinus exposure can be avoided if a transmeatal instead of a transcortical route is used (Fig. **25**) and a canal wall–down mastoidectomy instead of a canal wall–up mastoidectomy is performed.

In skull base surgery and acoustic neuroma surgery, total exposure of the sigmoid sinus is necessary at an early stage of the bone work (Fig. **172**). The advantage of total exposure of the sinus wall is that the sinus is then easy compressible, but the disadvantages are that the sinus wall can later be damaged by the rotating shaft when drilling in a deeper part of the temporal bone, or by the use of sharp instruments.

In decompression or other surgery of the endolymphatic sac, the inferior part of the sigmoid sinus has to be exposed (Fig. **173**) in order to remove the bone covering the sac. In fact, the safest method of endolymphatic sac decompression is via total exposure of the sigmoid sinus and the posterior fossa dura, before carefully searching the lateral edge of the sac (Fig. **174**). After identifying this edge, further decompression of the sac is a relatively easy and safe procedure, and searching for the posterior semicircular canal is seldom necessary.

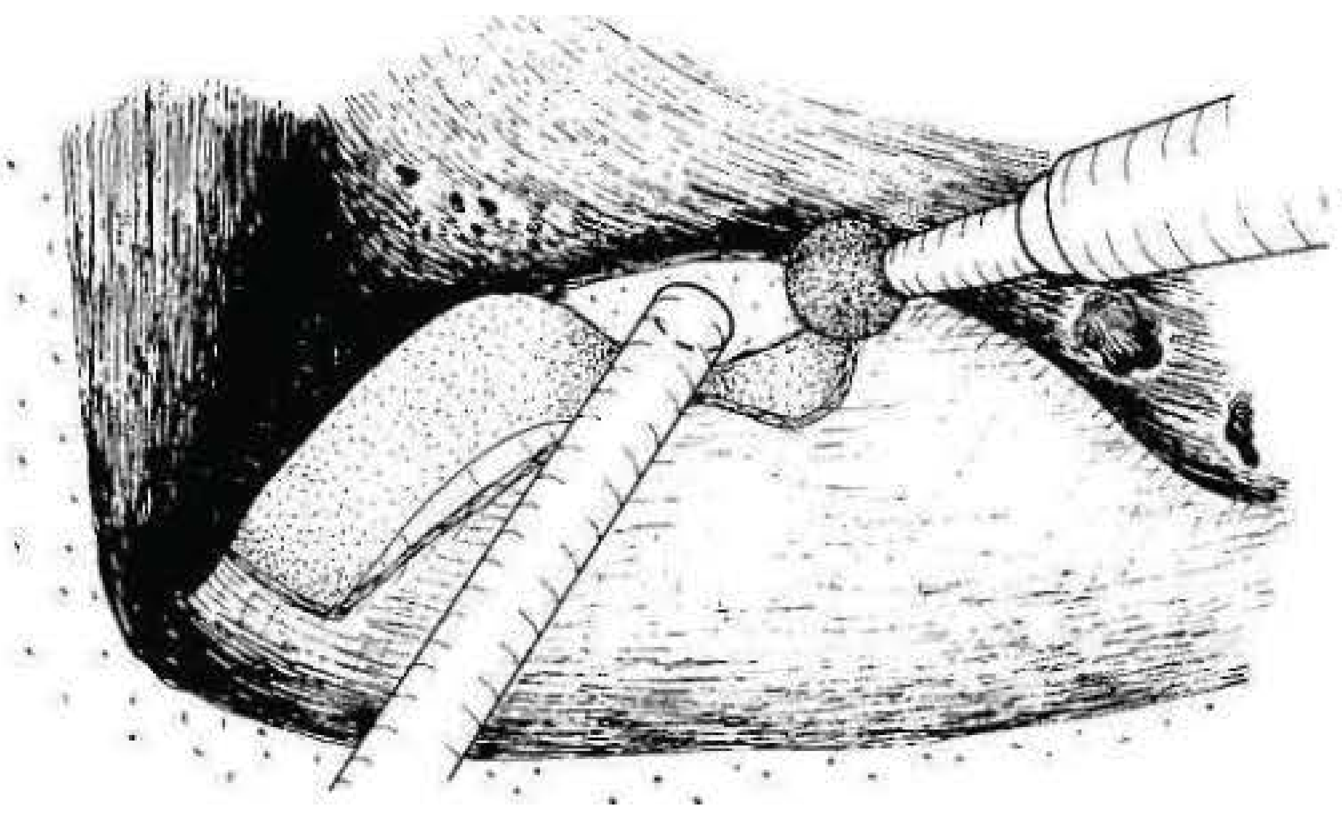


Fig. **168** The exposed sinus is depressed using a suction tube and the edges of the bone covering the sinus are drilled away

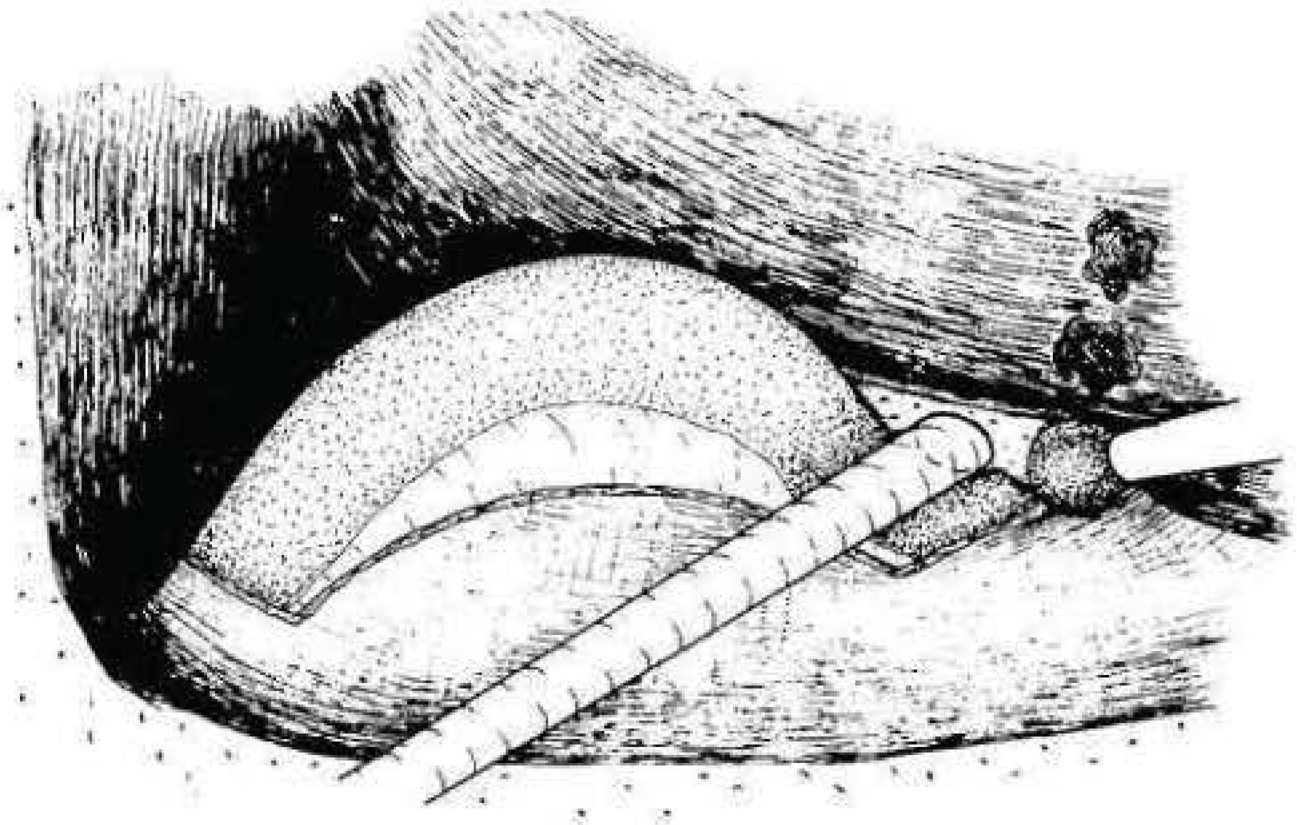


Fig. **169** The entire sinus has been totally exposed. The inferior part is covered and protected by a suction tube, and the inferior edge of the bone is being drilled away

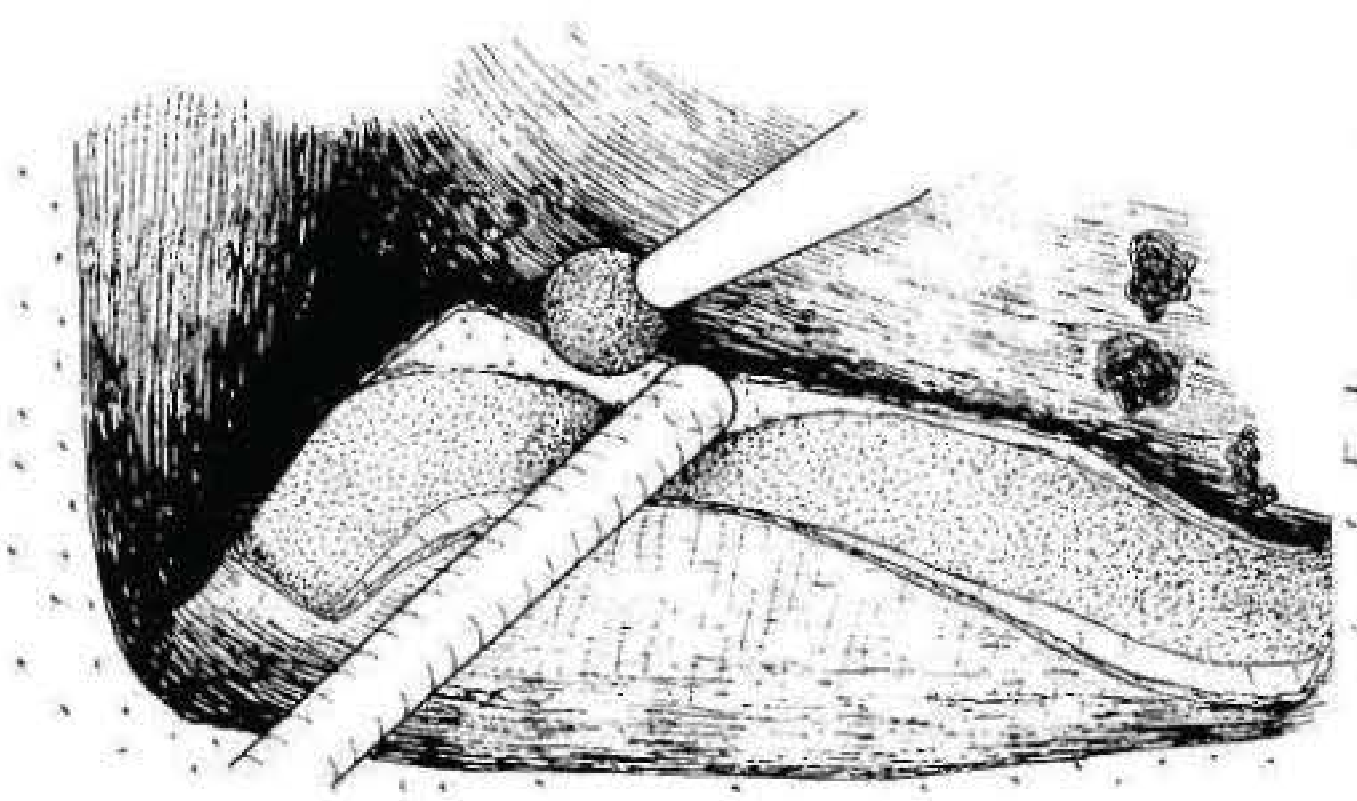


Fig. **170** Drilling of the anterior wall after exposure of the sinus. It can be depressed, and the anterior wall can be drilled away

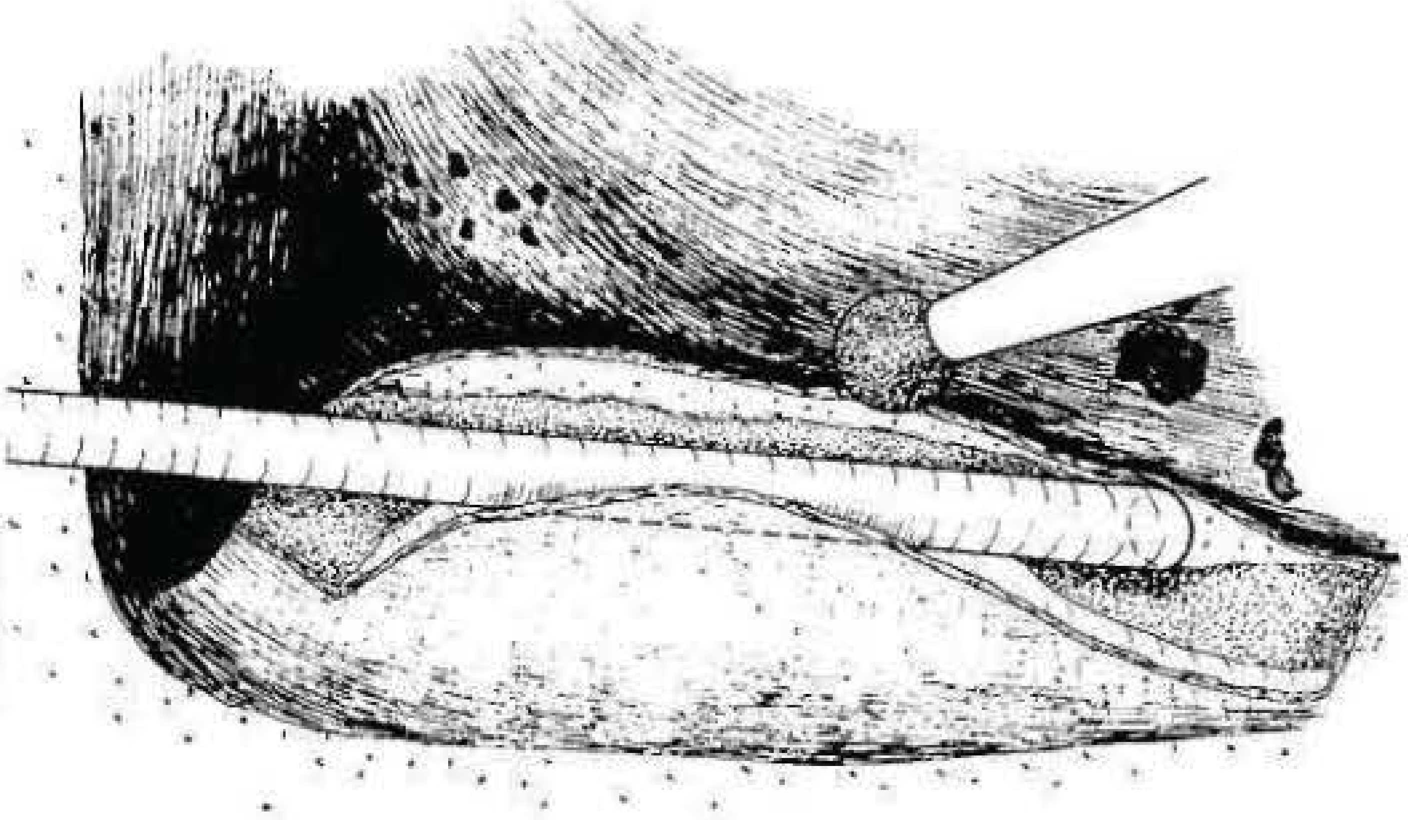


Fig. **171** **Protection of the exposed sigmoid sinus** and drilling of its anterior wall

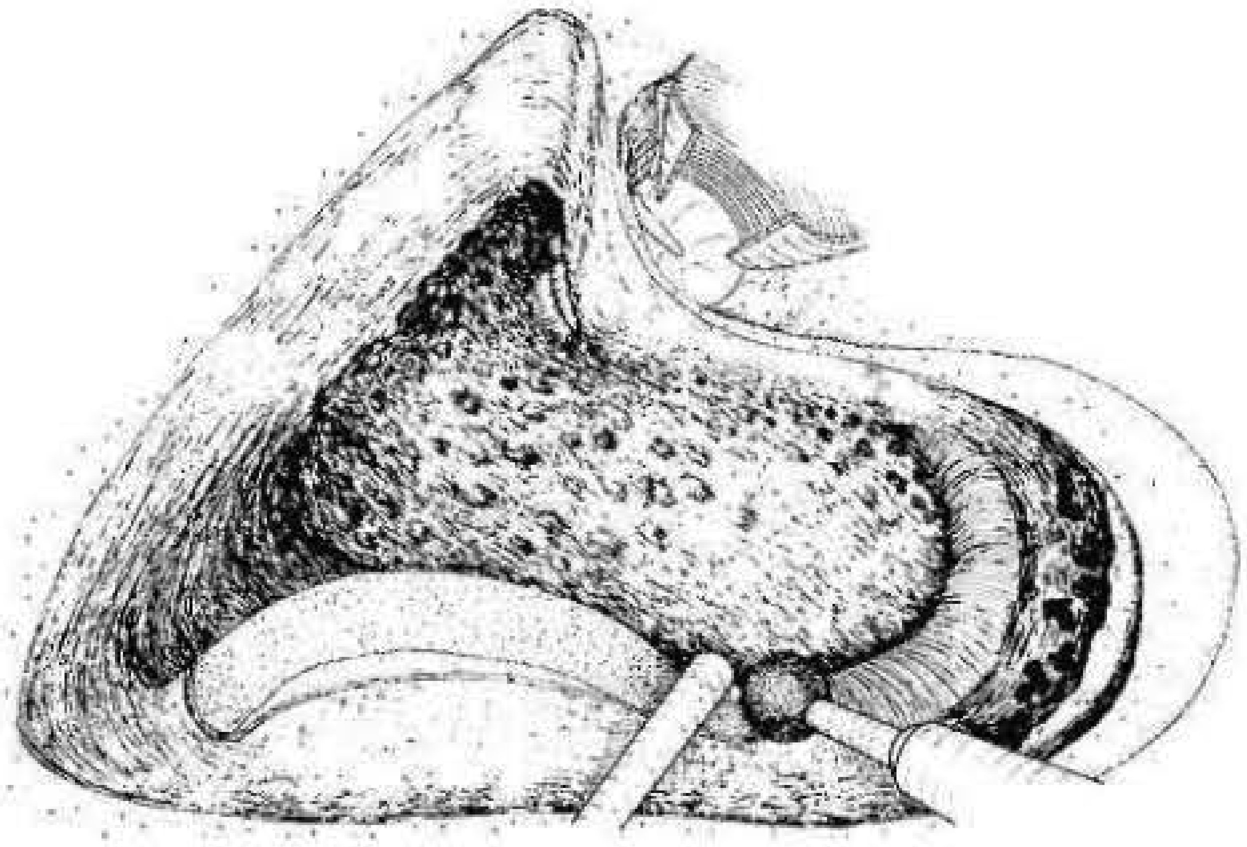


Fig. **172** **Total exposure of the sigmoid sinus at the beginning of the bone work for translabyrinthine surgery for acoustic neuroma**. The same exposure is used for decompression of the endolymphatic sac

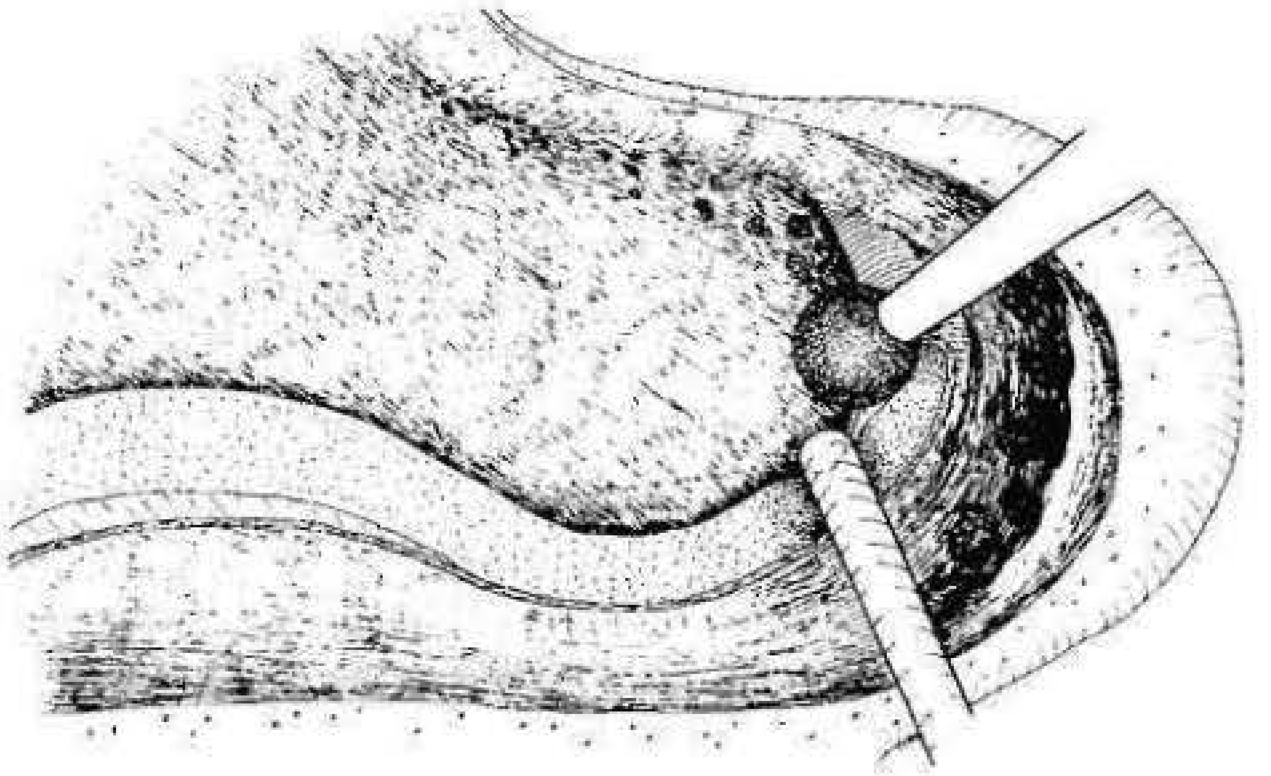


Fig. **173** **Decompression of the endolymphatic sac**, starting with total exposure of the sigmoid sinus down to the facial nerve

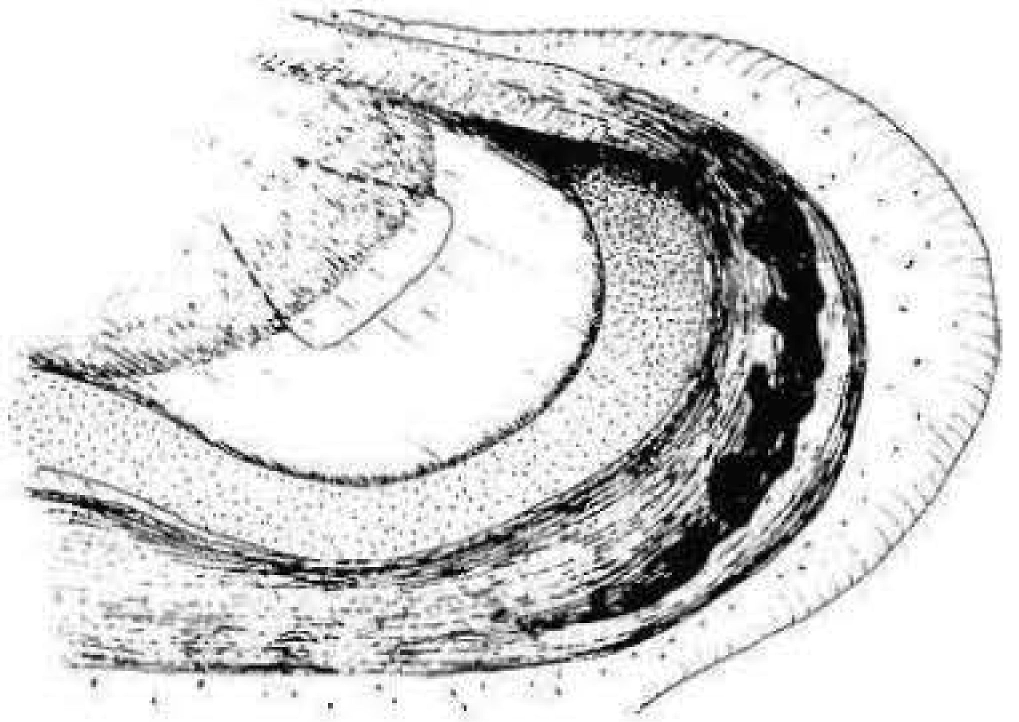


Fig. **174** After the inferior part of the sigmoid sinus has been exposed, the posterior fossa dura is gradually exposed, and the anterior and posterior edges of the sac are identified

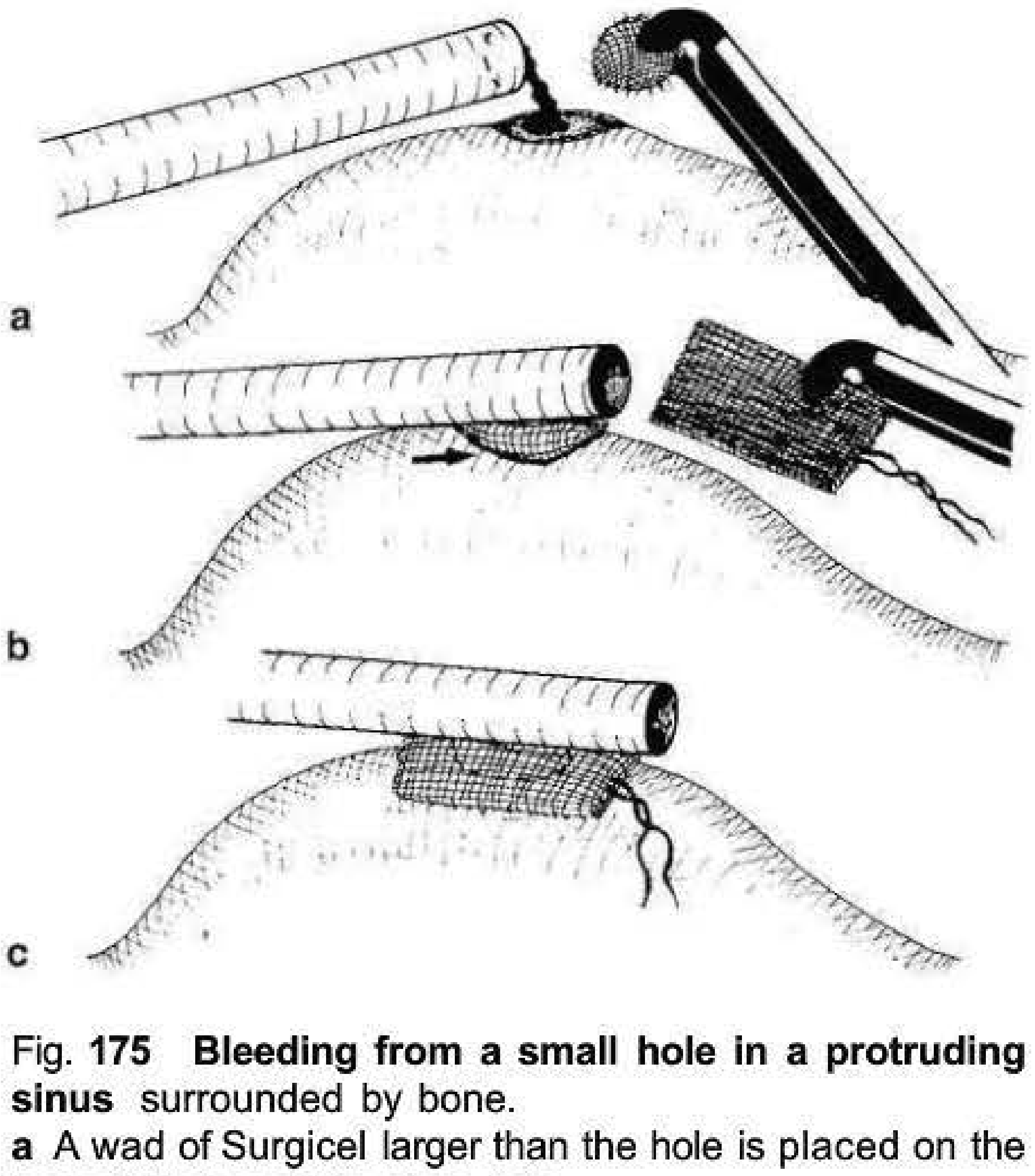


Fig. **175** **Bleeding from a small hole in a protruding sinus** surrounded by bone.

a A wad of Surgicel larger than the hole is placed on the bony defect and the sinus hole.

b The Surgicel is held in place with a suction tube, and pushes the edges of the sinus inward (arrow). It lies partly in the hole, partly between the sinus wall and the bony wall, but mainly outside the bony wall.

c The Surgicel is covered by a cottonoid held in place with a suction tip for some minutes

Bleeding from the Sigmoid Sinus

During removal of bone, the sigmoid sinus can be torn either with a cutting burr, a small diamond burr, sharp instruments, or a chisel. Sharp edges of bony fragments can pierce the sinus wall, resulting in brisk hemorrhage.

Small holes, when they have occurred inadvertently using a small cutting burr on a protruding sigmoid sinus and where the remaining bone is *not removed,* can be covered with a ball of oxidized cellulose (Surgicel or Oxycel) of a larger diameter than the hole (Fig. **175a**), which is pressed firmly over the bony defect with a suction tube. In this way, the Surgicel plugs the opening of the sinus wall and causes some inversion of the edges of the hole into the lumen of the sinus. The same piece of Surgicel lies partly within the hole, between the sinus and its bony wall (Fig. **175b**), as well as outside the bone. This type of seal is usually effective, but if there is still bleeding, a small cottonoid can be placed over the Surgicel and held in place with a suction tube or a rougine (Fig. **175c**). After a few minutes, the cottonoid can be removed and the drilling continued.

Small lacerations of the exposed sigmoid sinus can be sealed using bipolar cautery, placing the cautery tangentially onto the sinus wall, and gently coagulating the edges of the small leak (Fig. **176**). In general, spot coagulation of the sinus wall is not reliable, and if the first attempt does not stop the bleeding or significantly diminish the leak, further coagulation is not recommended, since the leak may enlarge. Placing a plug of Surgicel followed by a

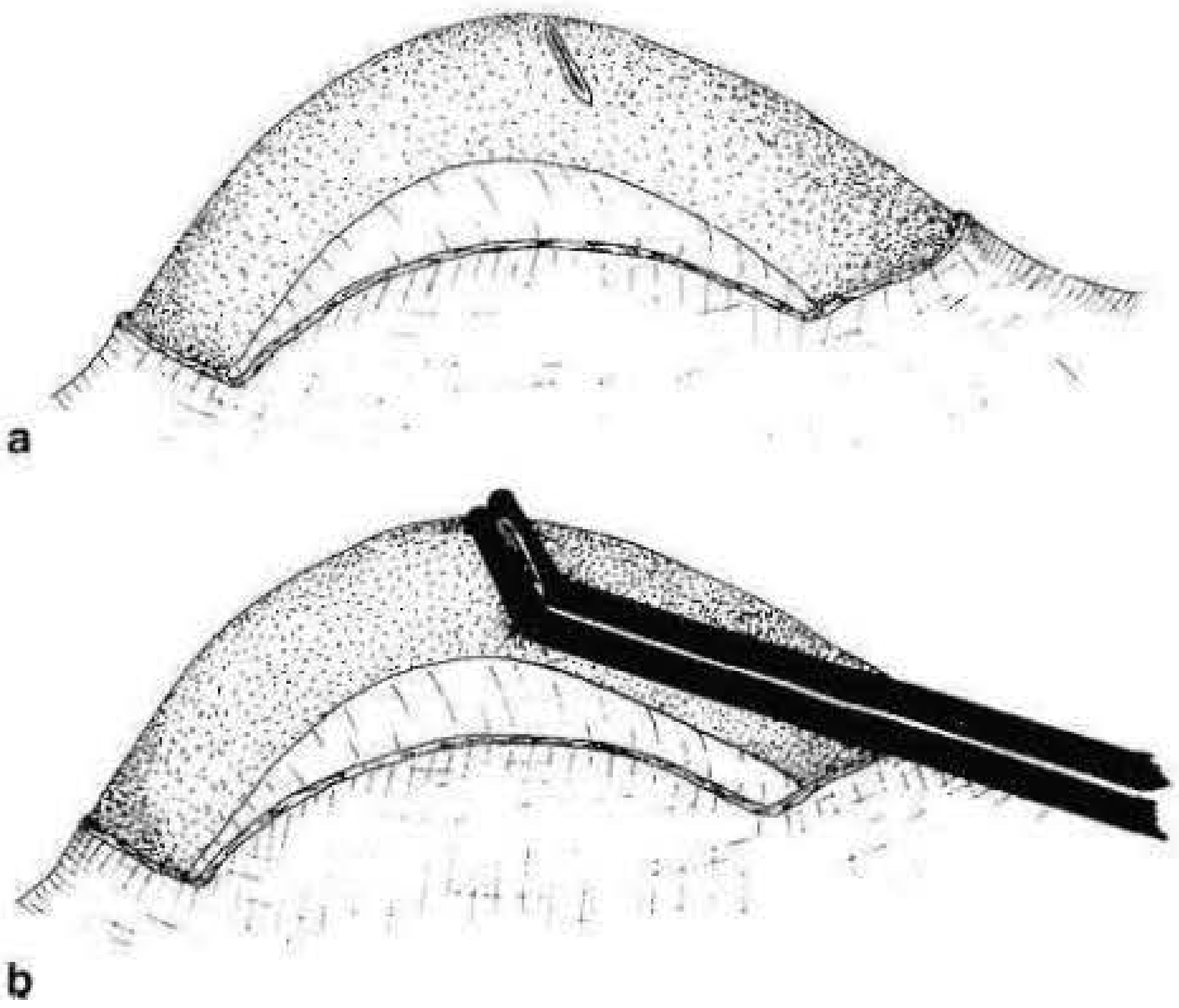


Fig. **176a** **Coagulation of a small tearing** of the sigmoid sinus.

b A curved pincette coagulates the edges together piece of cottonoid also stops the bleeding from small tear (Fig. **175**). If a small venous bleed is not disturbing drilling it can be ignored; sometimes irrigation with water stops the bleeding.

Bleeding from the occipital emissary vein (Santorini) can occur close to the posterior aspect of the sigmoid sinus or along its course through the temporal or occipital bone as far as the mastoid foramen (Fig. **52**). If the tear is located at the junction of the emissary vein into the sinus, the bleeding may be difficult to stop, but usually a tangentially placed bipolar coagulation can "glue" the tear (Figs. **177 a, b**). Bleeding from the emissary vein within the bone posterior to the sinus has to be arrested using bone wax (Fig. **177c**).

A large laceration of the sinus may appear during removal of the bone fragments attached to the sinus, or inadvertently with the burr. With severe bleeding from the sinus where it is not surrounded by bone, and when closure as described in Figure **175** cannot be performed, the bleeding has to be stopped by obliteration of the sinus. Before obliteration, the bony fragments attached to the sinus have to be removed. During removal of the bony fragments, the bleeding may be slowed down by occlusion of the hole with a flat instrument, a finger, or a piece of gauze. After removal of the bony fragments, extraluminal or intraluminal obliteration of the sinus can be performed.

Extraluminal obliteration. Using a piece of gauze as well as a finger, the opening is held closed until a large sheet of Surgicel is ready to replace the gauze (Fig. **178a**). With a large suction tube, the Surgicel is held in place over the hole and is adapted to the course of the sinus (Fig. **178b**). Using a Freer's rougine, the Surgicel is placed between the sinus wall and the bone (Fig. **179a**) partly obliterating the sinus (Fig. **179b**). If there is still a leak, a fresh piece of Surgicel can be used (Fig. **179c**). The surgery can then continue. The second gauze can be removed before closure, or earlier if it hampers the view during surgery.

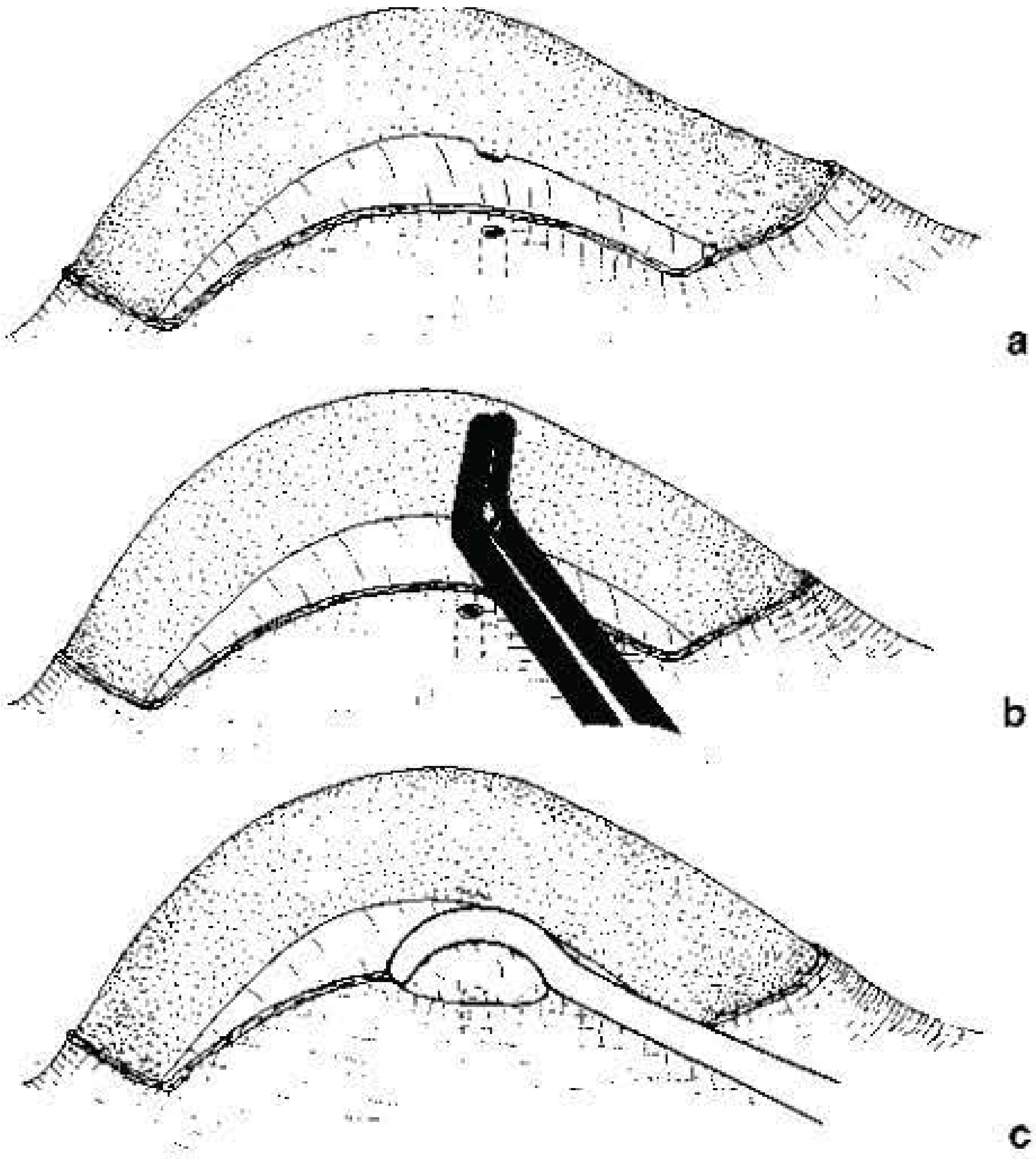


Fig. **177a** **Bleeding from the occipital emisary** with a leak at the entrance of the emisary vein into the posterior aspect of the sinus.
b The edges of the leak are coagulated with a bipolar pincet.
c The emisary hole in the bone is blocked by a piece of bone wax placed onto the hole with a Freer's rougine

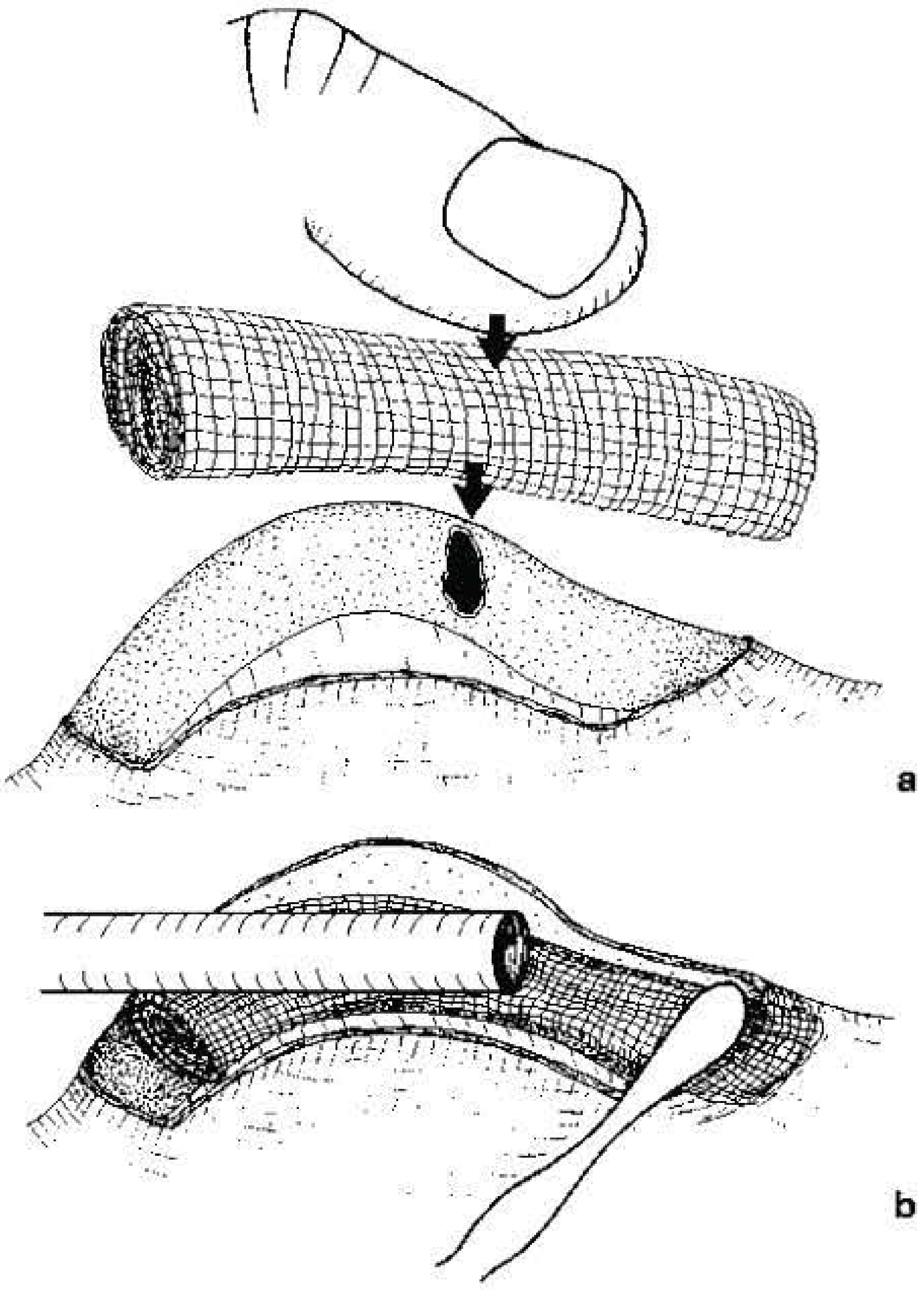


Fig. **178** **Extraluminal obliteration of a larger hole in the sigmoid sinus.** ▷
a With a finger and a piece of gauze, the bleeding from the hole is stopped until a large piece of Surgicel is ready to be placed on the hole and sigmoid sinus.
b The Surgicel is placed on the hole and adapted along the course of the sigmoid sinus. Using a Freer's rougine, the Surgicel is placed between the sinus and the bone

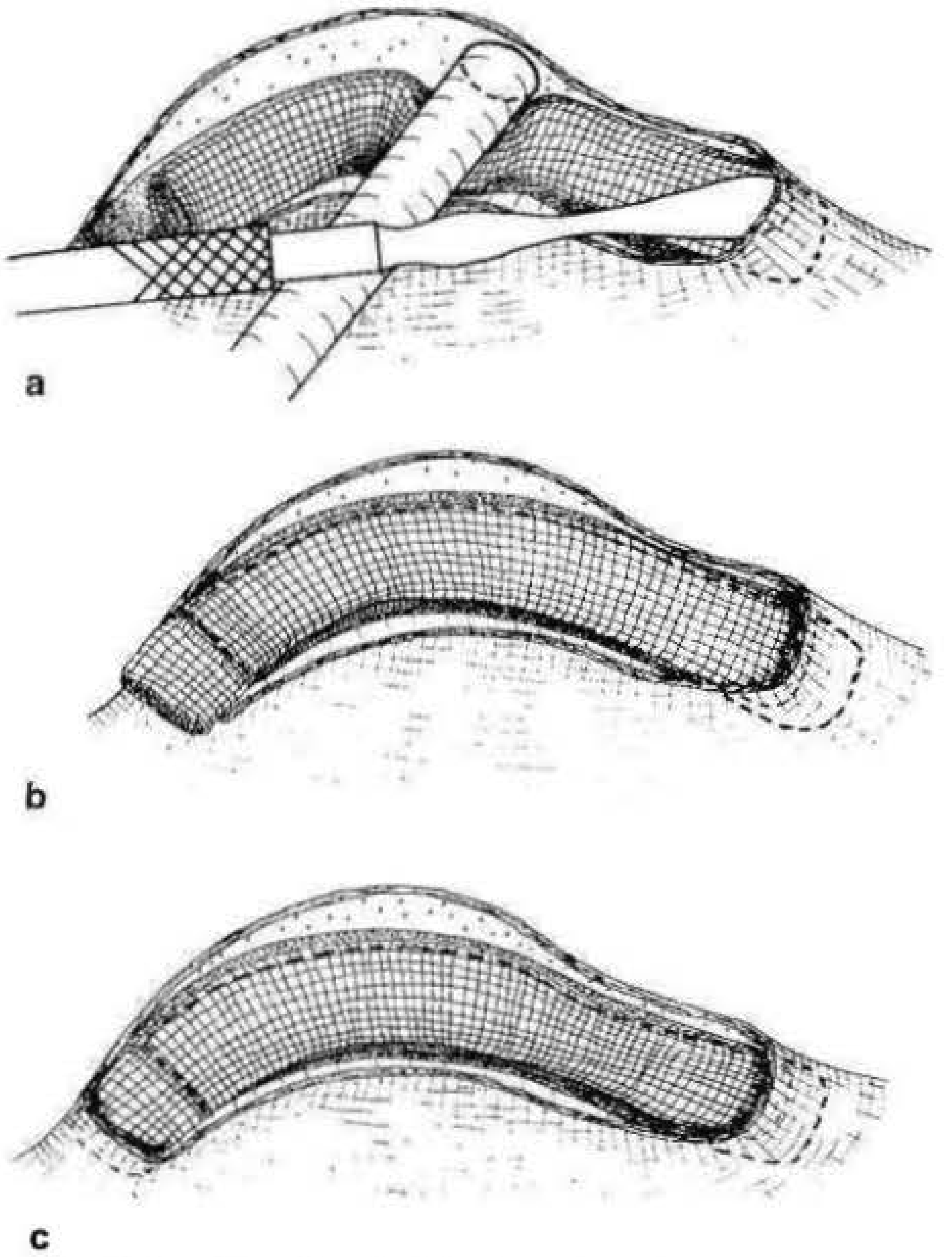


Fig. **179a** The Surgicel is placed under the bony edge and on the sinus, covering the hole and the entire course of the exposed sinus.
b A new piece of Surgicel is placed on top of the previous one to further secure the intraluminal obliteration of the sigmoid sinus.
c The ends of the Surgicel are placed between the sinus and the bone

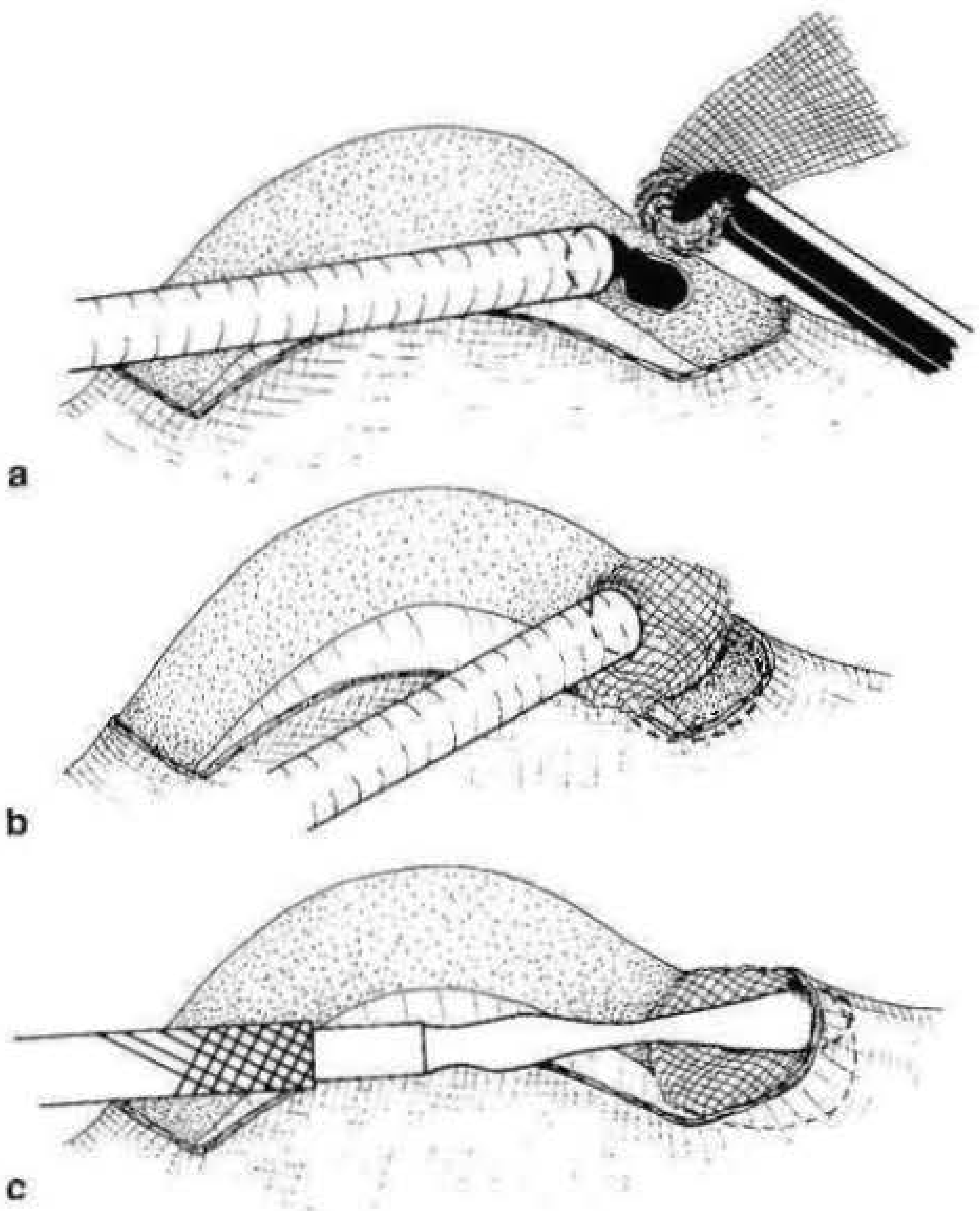


Fig. **180a** **Intraluminal obliteration in a large sigmoid sinus hole**. A large stip of Surgicel is rolled together on one side into a ball, which is placed through the hole into the sinus, blocking the hole from inside and partly or totally obliterating the sinus.
b The major part of the gauze is placed outside the sinus.
c **Intraluminal and extraluminal obliteration**. The Surgicel ball is placed in the sinus through the hole, and the external part of the Surgicel is placed outside, between the bone and the sinus, further obliterating the sinus

Intraluminal obliteration. A large wad of Surgicel is partly placed intraluminally. A large single sheet (Fig. **180a**) is used to prevent embolization, and the remaining half of the sheet is placed externally over the hole (Fig. **180b**). In order to prevent embolization, the major part of the Surgicel should be outside the hole. This type of intraluminal obliteration is usually used in combination with an extraluminal obliteration. Further Surgicel can be placed over the sinus to maintain the position of the first piece.

Intraluminal and extraluminal obliteration (Fig. **180c**). After placing part of the Surgicel in the lumen, as shown in Fig. **180b**, the outer part is placed between the sinus and the bone, producing extraluminal pressure over the intraluminal portion (Fig. **181**).

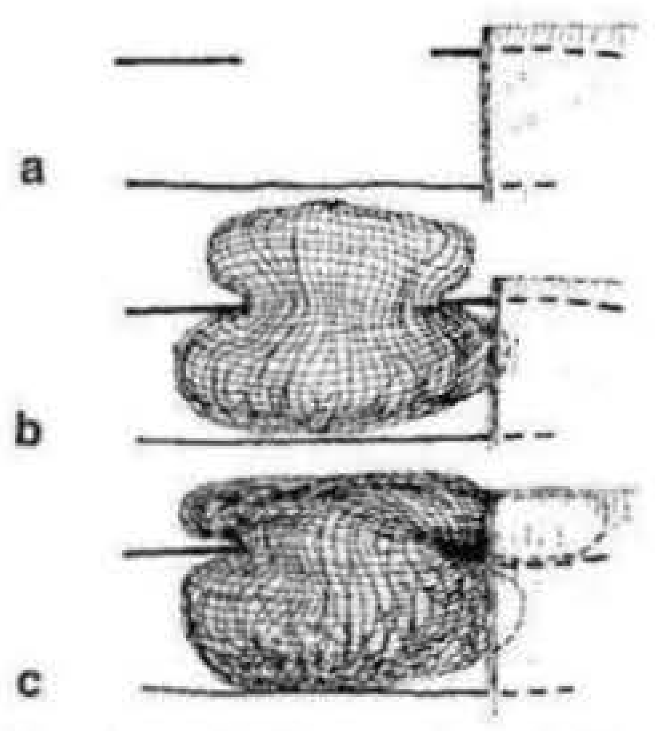


Fig. **181a** Side view of a large sinus hole.
b A piece of Surgicel is obliterating the sinus and closing the hole from inside.
c Part of the same piece of Surgicel is placed between the sinus wall and the bony wall

The problem with packing a bleeding point either intraluminally or extraluminally is the effect of the pack on further drilling or other surgery. The pack may be dislocated or even pulled out by the burr, resulting in fresh bleeding or a larger tear. Small Surgicel packs placed at the border of the bone can be effectively protected by covering them with bone wax.

Any excess Surgicel is trimmed away using a pair of scissors, and the compressed sinus is covered with *bone wax* to prevent dislocation of the pack during subsequent surgery. The packing is occasionally difficult to keep in place, particularly in the region of sinodural angle. When this occurs, the packing can be stabilized by sutures placed through the dura on both sides of the sinus above the sinodural angle. This procedure is time-consuming and technically more difficult than direct intraluminal or extraluminal packing.

In rare cases in which bleeding cannot be controlled by packing or cautery, it is necessary to pack the entire lumen of the sigmoid sinus above and below the laceration. Hemorrhage is controlled temporarily by external compression with a pack in the mastoid. The internal jugular vein is then exposed and ligated through a transverse incision along the anterior border of the sternocleidomastoid muscle at the level of hyoid bone. Ligation of the jugular vein need not be high in the neck. The purpose of ligation is to prevent embolization of packing material from above. During the procedure of ligating the vein, care should be taken to locate the accessory nerve which usually runs posteriorly over the lateral process of C1, or just below it.

Severe bleeding from the sigmoid sinus is rare, and in our series of 600 acoustic neuromas we have never found it necessary to ligate the jugular vein. The sigmoid sinus was exposed in nearly all 600 cases, but we have never encountered a tear in the sinus that could not be stopped, usually by extraluminal obliteration, and we have always been able to proceed with the surgery.

In middle ear surgery, bleeding from the sigmoid sinus is also rare, but it may occur, especially in revision mastoidectomies with a previously exposed sinus. The surgeon should be prepared for this complication. One or two large pieces of Surgicel should always be unpacked in the operating room and easily available to the scrub nurse.

Total Exposure of the Posterior Fossa Dura

The bone lying medial to the sigmoid sinus covering. the posterior fossa dura is usually thinned and smoothed after exenterating all air cells using a large diamond burr.

In surgery for chronic middle ear disease, it is seldom necessary totally to expose the posterior fossa dura. However, in cases with cholesteatoma eroding the bony plate of the posterior fossa dura, total exposure of the dura is necessary in order to clear the cholesteatoma matrix surrounding the bony overhangs (Fig. **182**). In such cases, it is best to expose the sigmoid sinus totally, protect it by pushing it posteriorly with a large suction tube, and remove the bone with a large diamond burr (Fig. **183**). The posterior fossa dura will in this way be exposed, and can be protected so that the bone lying anterior to it can be drilled away (Fig. **184**). By stepwise drilling of the bone covering the posterior fossa dura, the entire bony plate can gradually be removed if necessary.

Sometimes remnants of bone remain attached to the sinus or the dura at the junction between the sigmoid sinus and the posterior fossa dura, and it is

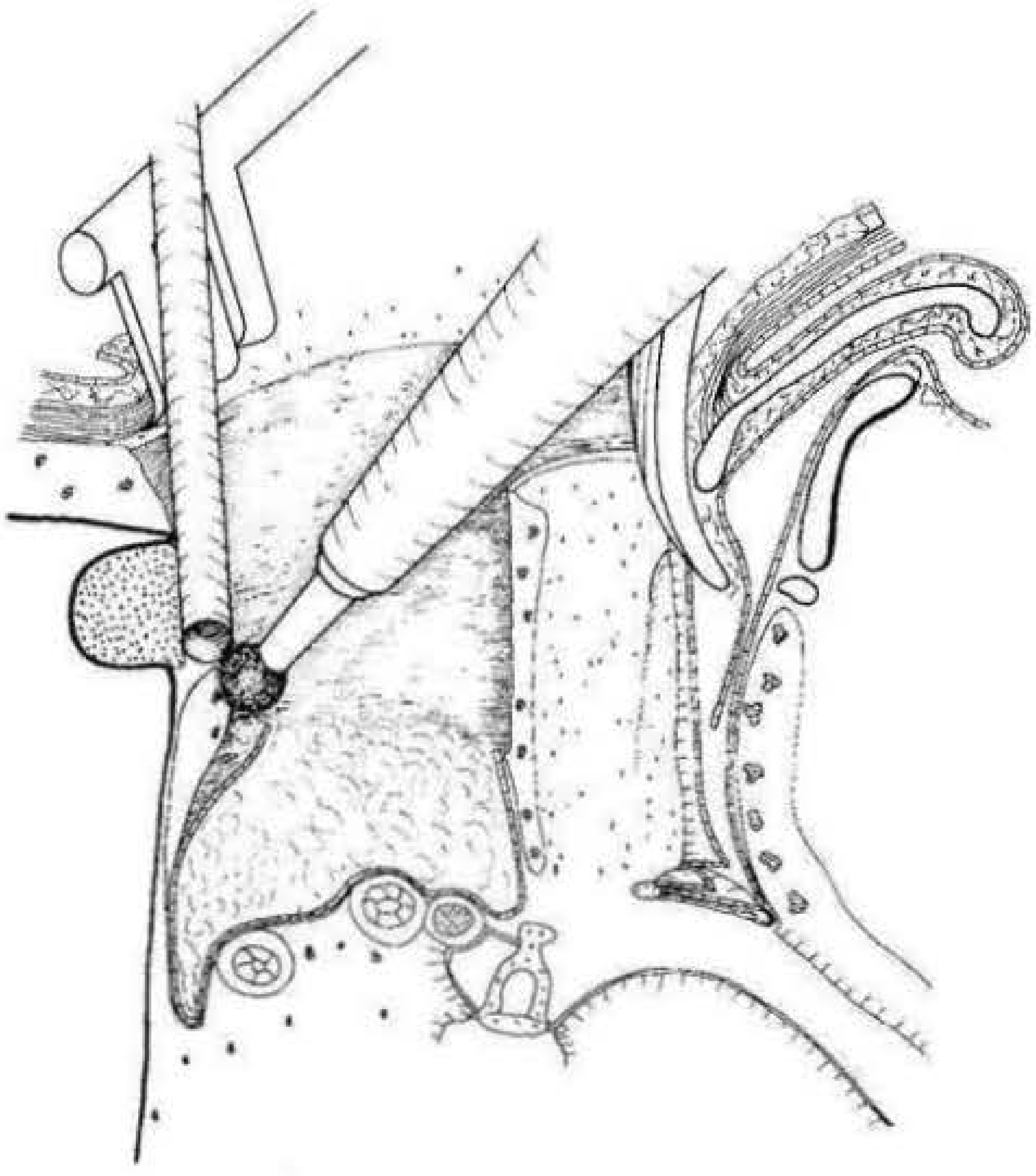


Fig. **182** **Side view of protection of the posterior fossa dura** in the sigmoid sinus during removal of the posterior bony plate in a case of cholesteatoma that had reached the posterior fossa dura

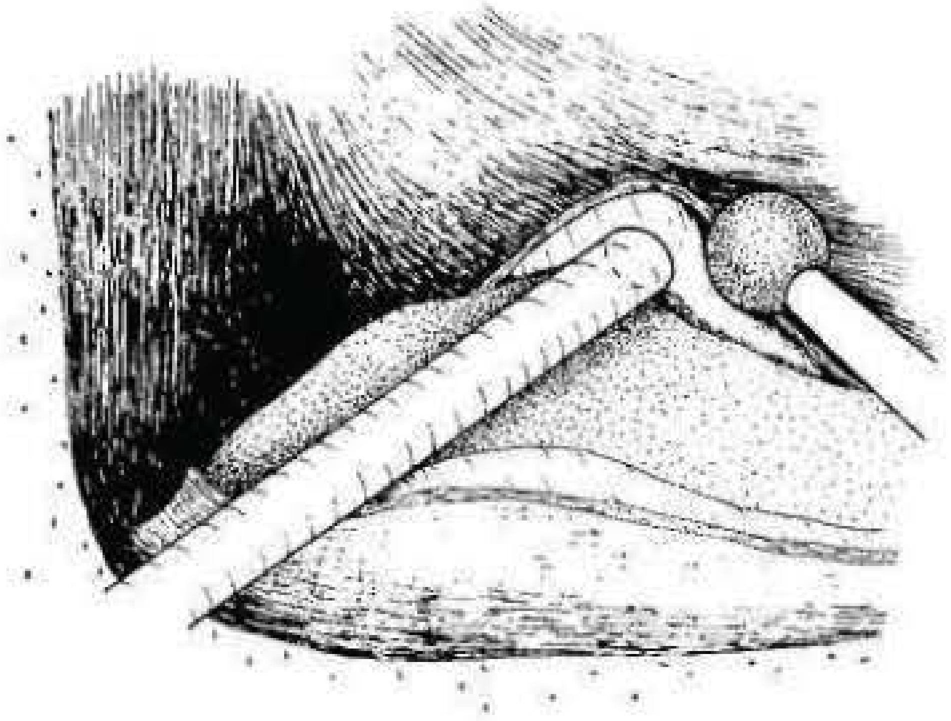


Fig. **183** **Exposure of the posterior fossa dura**. After total exposure and depression of the sigmoid sinus, the posterior fossa dura is pushed posteriorly by the suction tube, and the bone is safely drilled away with a large diamond drill

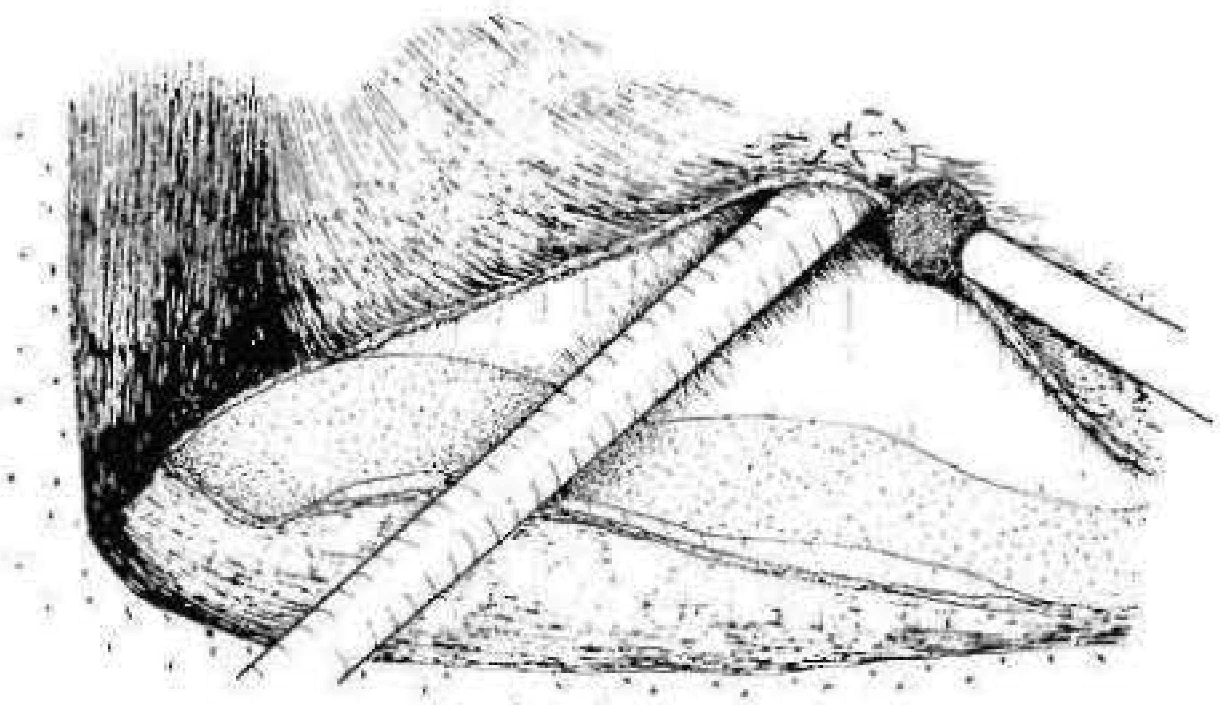


Fig. **184** Further exposure of the posterior fossa dura, which is protected by a suction tube placed between the dura and the bony plate

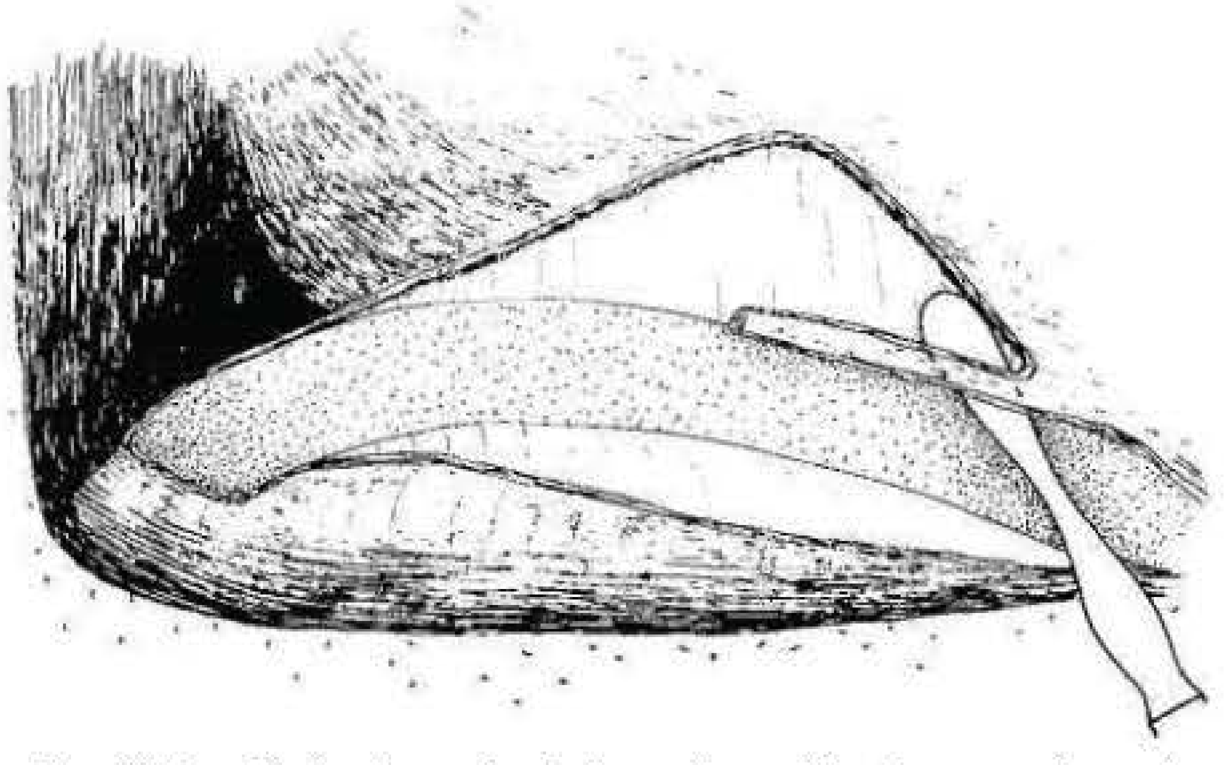


Fig. **185** Detachment of the sigmoid sinus and posterior fossa dura from a bony remnant lying at the border between the sinus and the dura. The bony bridge can now safely be drilled away or removed with a rongeur

difficult to drill the remaining bony plate away. The bone can be detached from the sinus and the dura using the Freer's rougine and drilled away or removed by a rongeur (Fig. **185**).

Larger exposure of the posterior fossa dura plate is necessary in cholesteatoma involving the perilabyrinthine space, i. e., the retrolabyrinthine or supralabyrinthine space. In such cases, a large curved retroauricular flap incision is placed 4 cm posterior to the postauricular fold, elevating a large skin–subcutis–muscle flap, as described in Volume 1, pp. 58–59, Figures **143–147**. In order to provide maximal space posteriorly, the flap is pulled far anteriorly over the auricle and held in place with surgical stays (Fig. **186**). The sigmoid sinus, the posterior fossa dura, and the posterior fossa dura are exposed, pushed posteriorly, and held in place with a suction tube to obtain access to the perilabyrinthine space and then elevate the cholesteatoma matrix (Figs. **187, 188**).

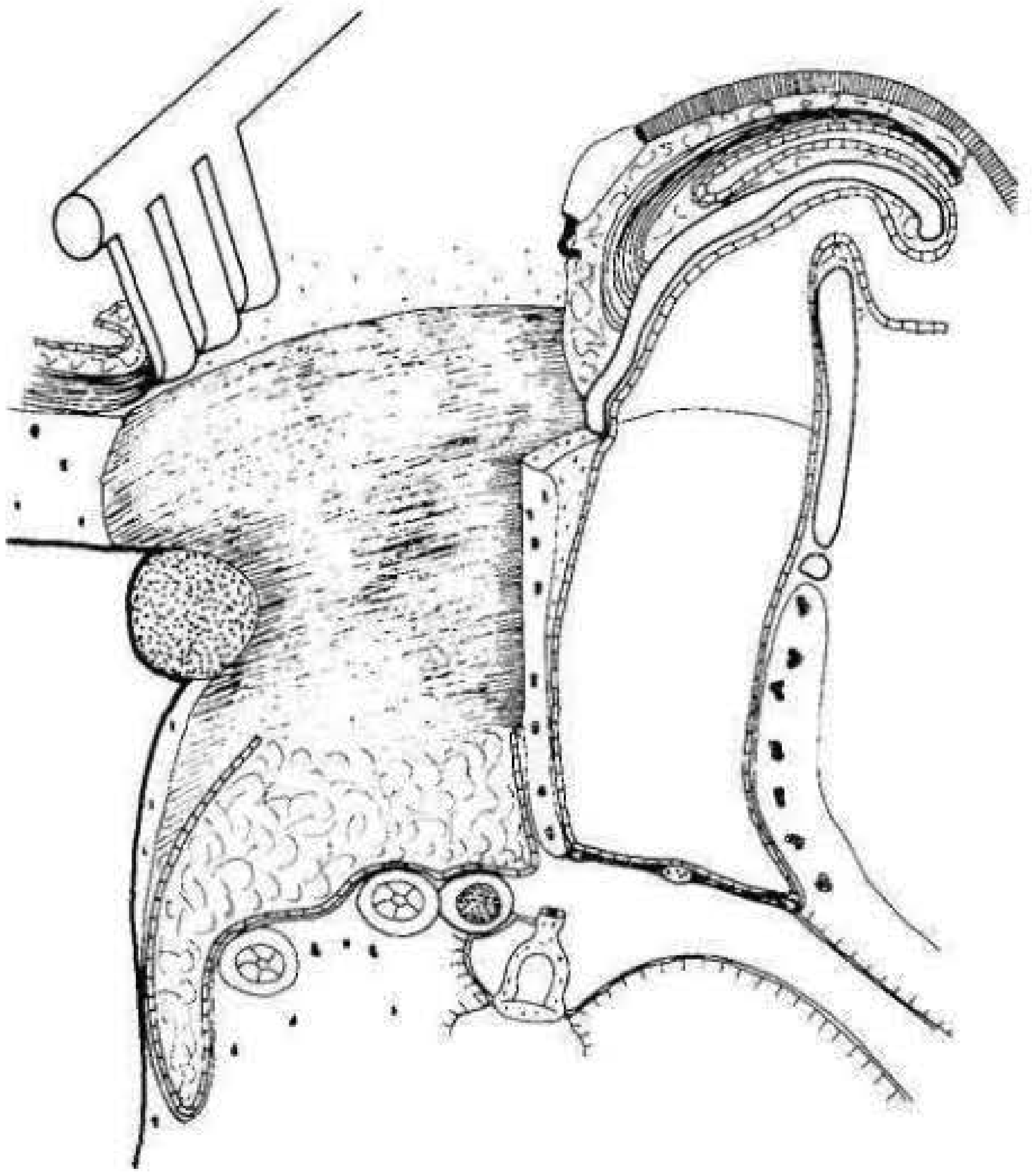


Fig. **186** **Side view of a case with an anteriorly positioned sinus, canal wall–up mastoidectomy, and a cholesteatoma** extending into the perilabyrinthine space between the posterior semicircular canal and the dura. A large retroauricular flap incision is performed 4 cm posterior to the postauricular fold, and the skin–subcutis–muscle flap is held in place by surgical stays to avoid using a selfretaining retractor, which hampers the view along the posterior fossa dura. The sigmoid sinus and the dura are exposed

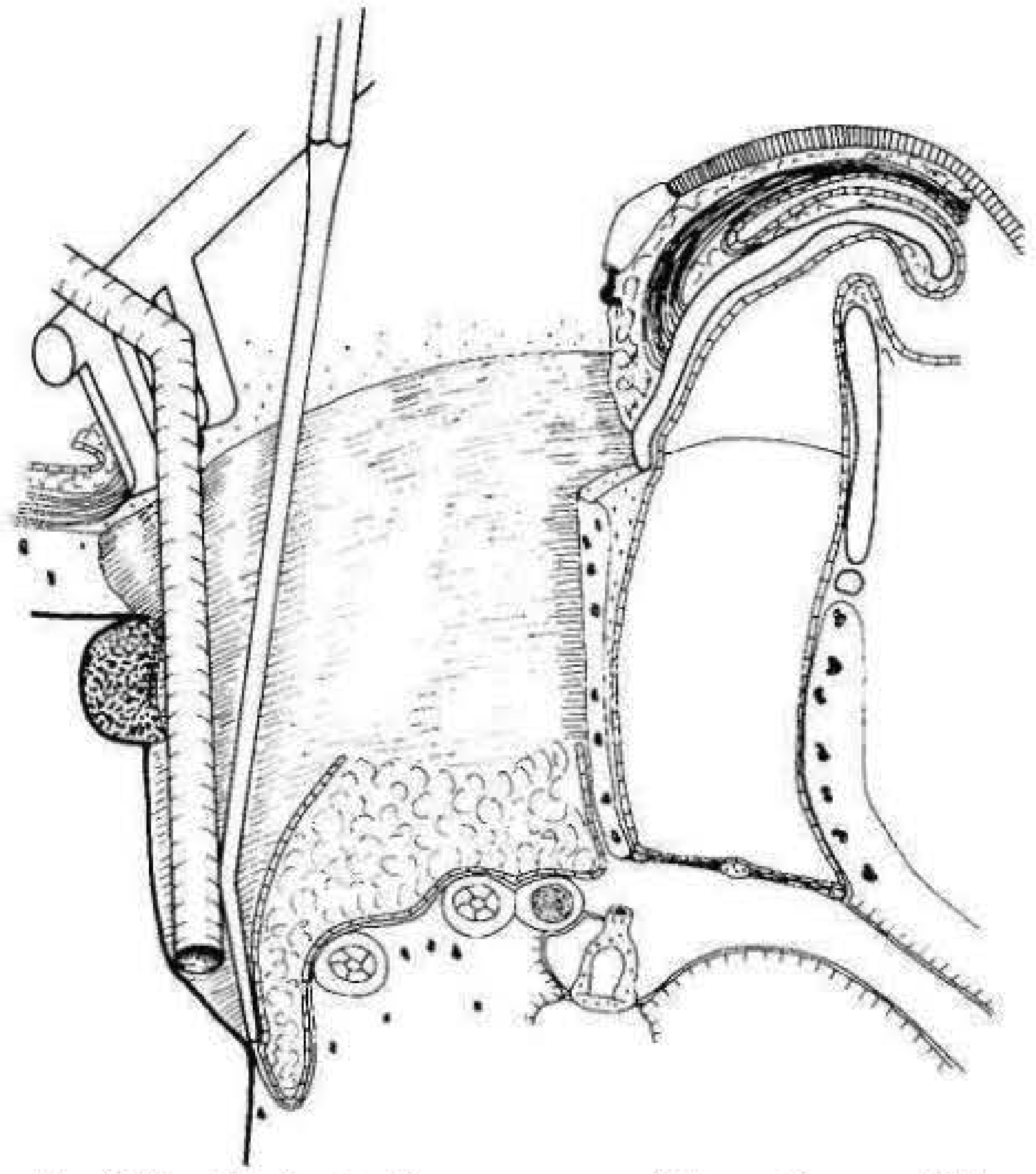


Fig. **187** **Cholesteatoma removal from the perilabyrinthine space**. The sigmoid sinus and the posterior fossa dura are displaced posteriorly and held in place with a suction tube, providing a good view of the retrolabyrinthine space and safe detachment of the cholesteatoma membrane from the dura

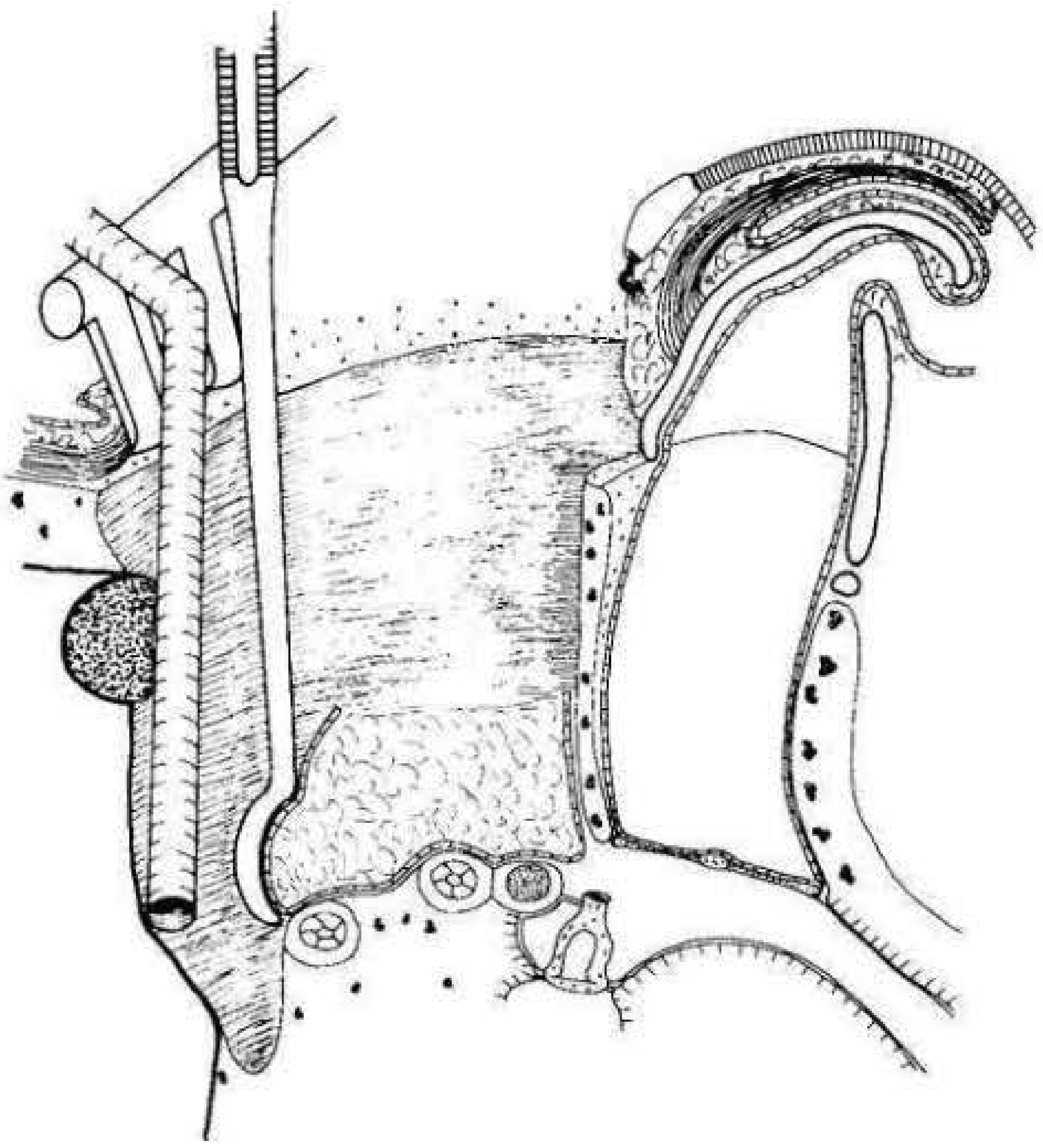


Fig. **188** The cholesteatoma has been removed from the retrolabyrinthine space

Entering the Mastoid Antrum

When illustrating the problems and techniques involved in dealing with the middle and posterior fossa dura and the sigmoid sinus, the Körner's septum has been passed and the antrum already opened in some figures (Figs. **134–145, 186–188**) before the method of how to pass the Körner's septum has been shown.

After locating the middle fossa dura and the sigmoid sinus and skeletonizing the bone of the mastoid tegmen and posterior fossa dura plate, the next step is to enter the mastoid antrum.

In ears with extensive pneumatization, it is relatively easy to enter the antrum. Using a small diamond or cutting burr, a cell lying posterosuperiorly at the level of Körner's septum is followed deeper towards the antrum by careful widening of the cell (Fig. **189**). Usually, the first such widened cell will open into the antrum. By further enlargement of other cells along the tegmen antri, the lateral wall of the antrum is gradually removed, and the surgical opening becomes wider (Fig. **190**). The drilling can now be extended superiorly along the tegmen antri (Fig. **191**) and inferiorly, in order to exenterate the mastoid cells along the posterior fossa dura plate toward the tip of the mastoid (Fig. **192**).

After further exenteration of the periantral cells and smoothing of the walls of the tegmen antri, as well as gradual thinning of the ear canal, the incus body, the malleus head, and the lateral semicircular canal become visible (Fig. **193**). These structures are the most important landmarks for the antrum, and a search should be made for them by careful thinning of the posterior bony ear canal wall using a diamond burr. This procedure is described in Chapter 6 below (pp. 112–114). In canal wall–down mastoidectomy, the search for the malleus and the incus is easier, since the bony canal wall can be removed. Even though the cutting burr is faster, it is advisable to use the diamond burr when exposing the anterior part of the antrum, to avoid peroperative sensorineural high tone loss.

In cases with limited pneumatization and a well-developed and thick Körner's septum, entrance to the antrum can be difficult, especially because it is smaller than usual in such cases. Drilling in the wrong direction can endanger the facial nerve or the lateral semicircular canal. The other possibility is that the antrum is not opened. In difficult cases with

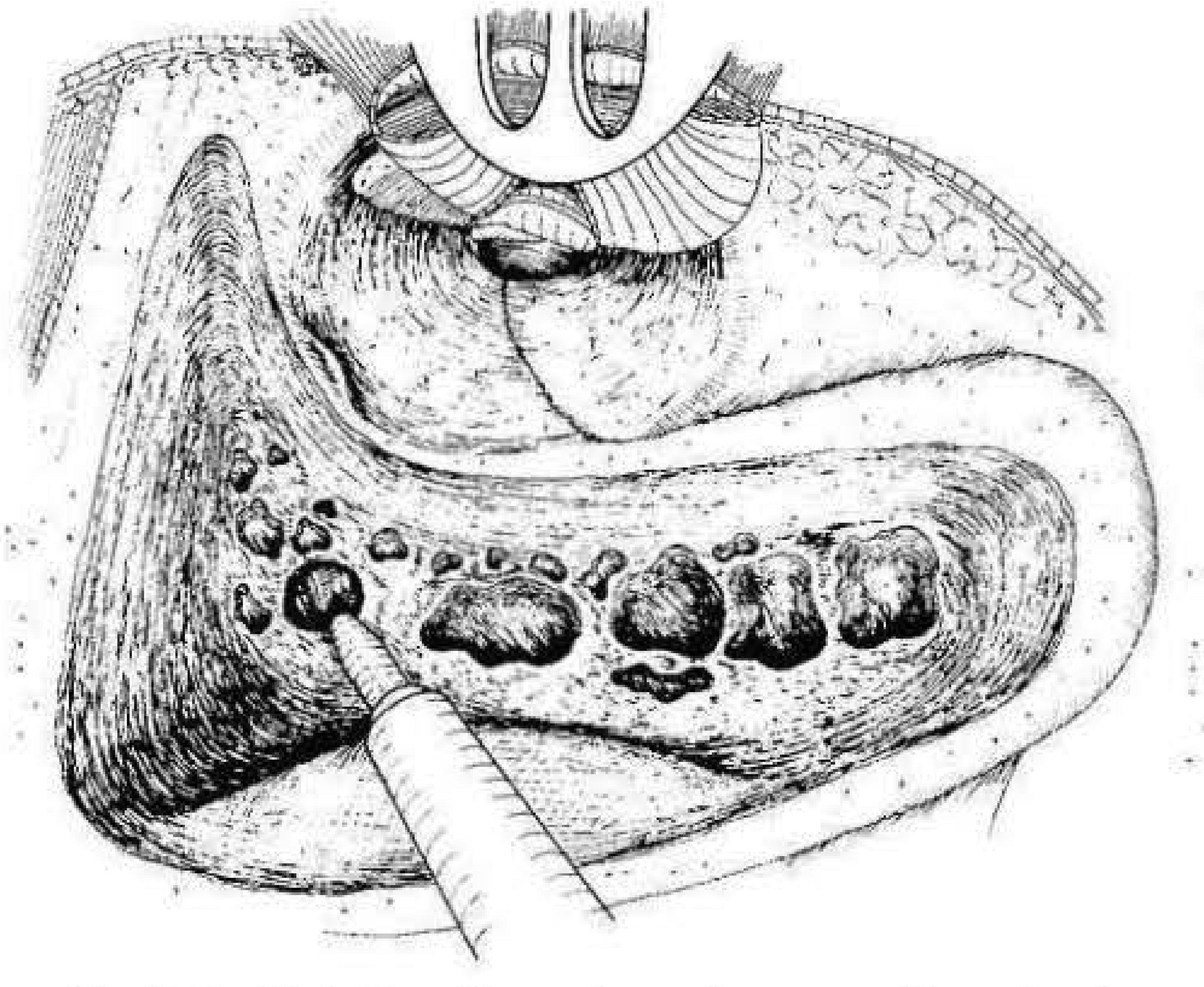


Fig. **189** **Entering the antrum** in case with extensive pneumatization. A small, sharp drill is inserted into an air cell, which is widened

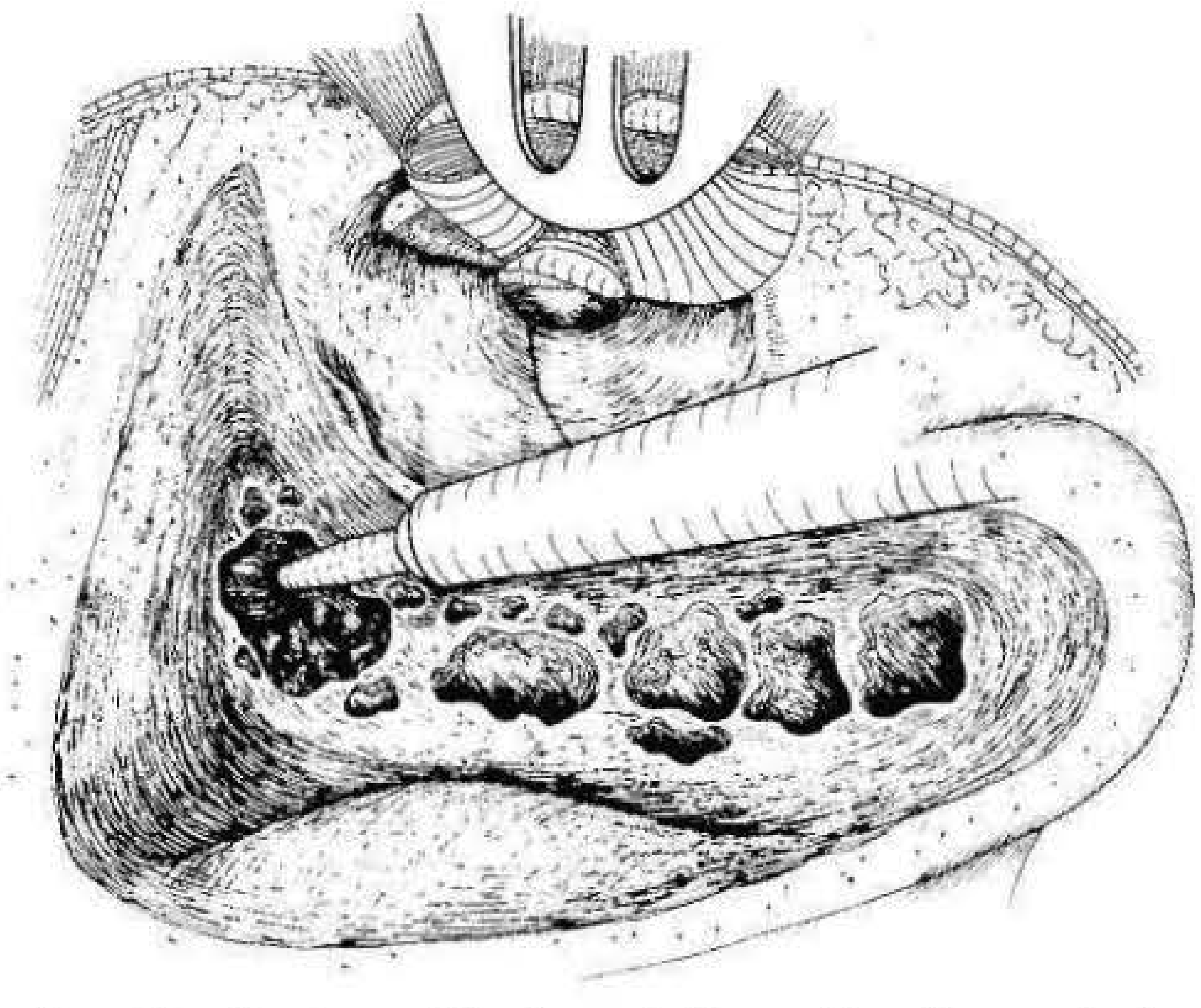


Fig. **190** Further widening of the cell, with gradual removal of the thin Körner's septum

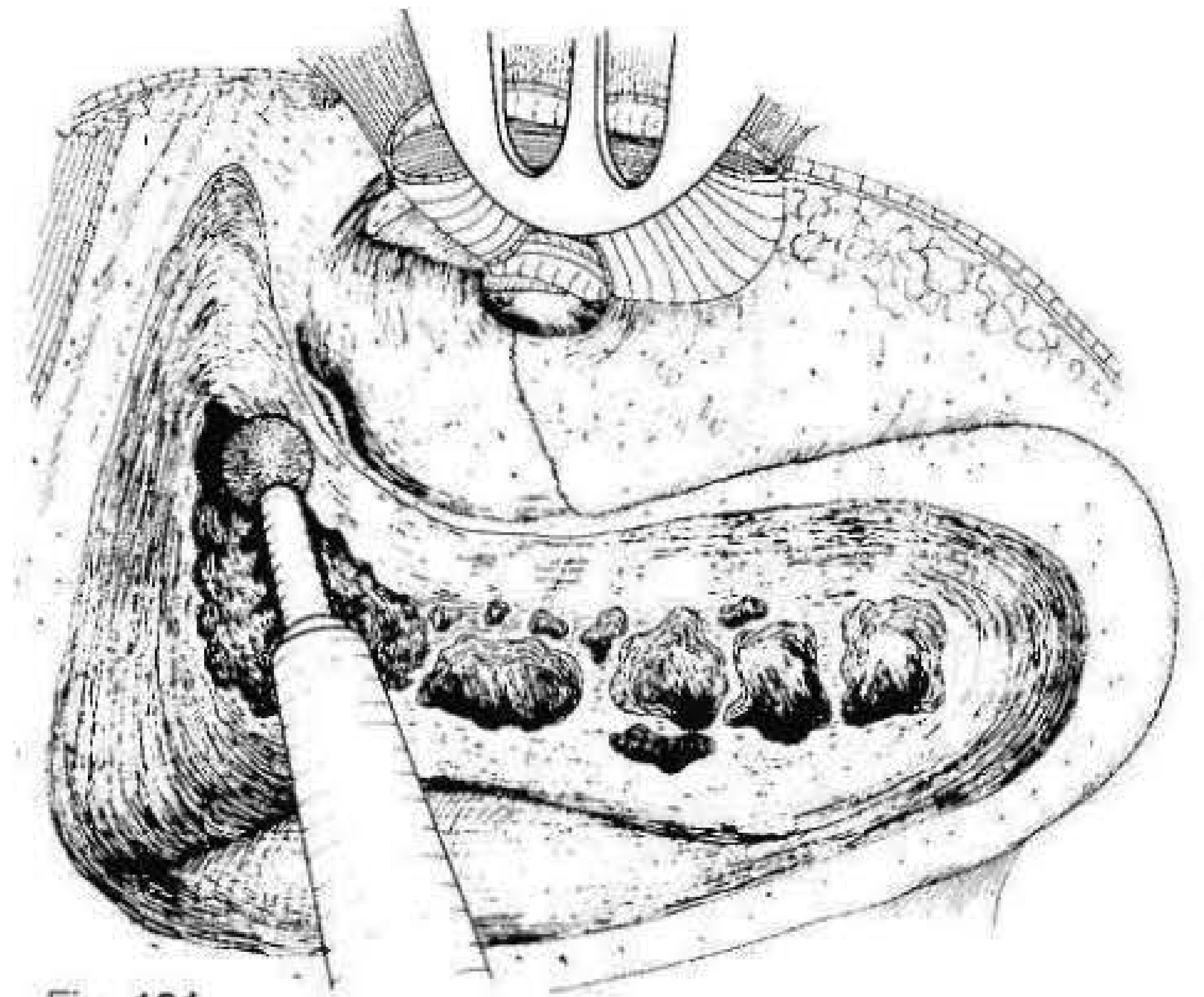


Fig. **191**

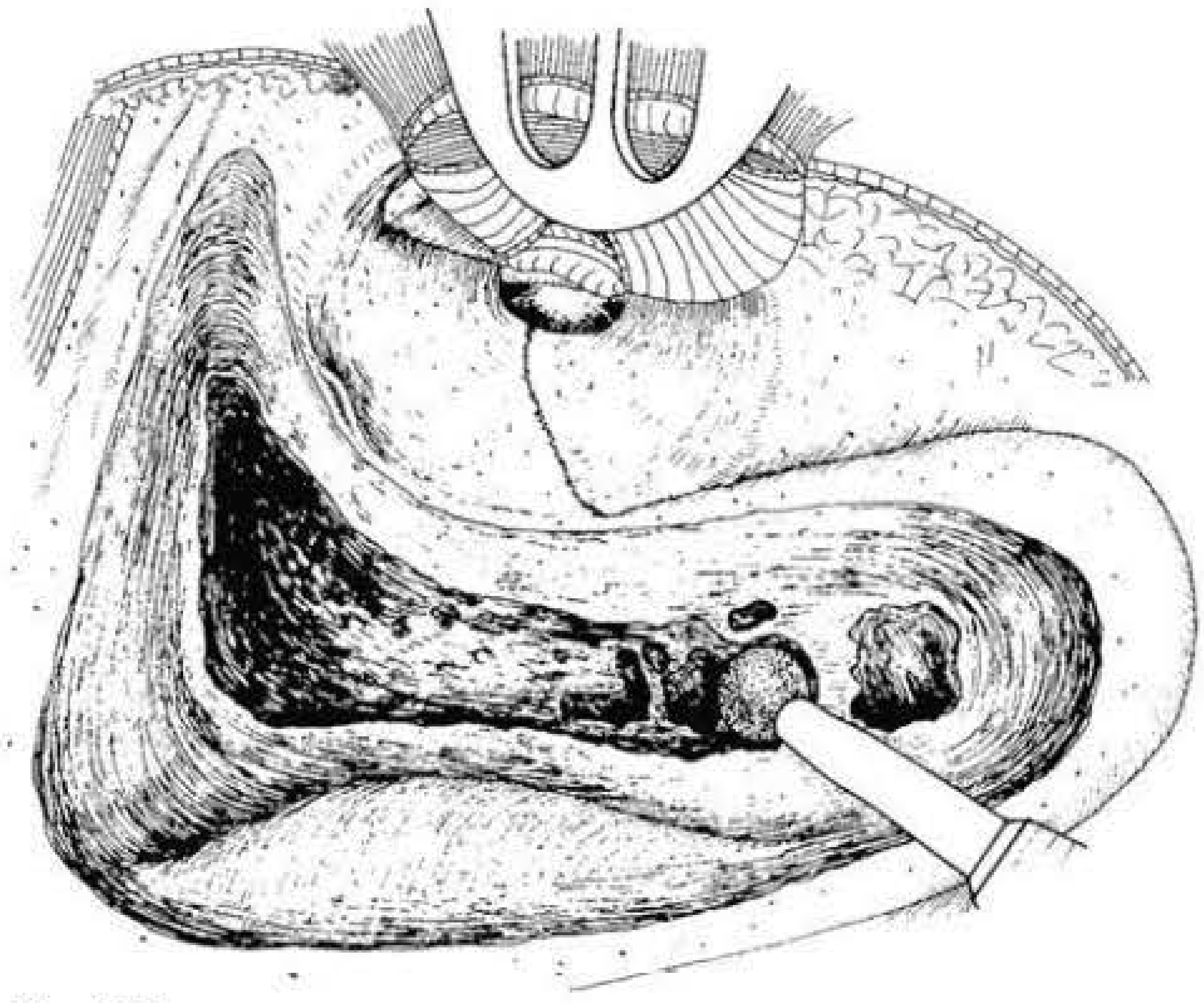


Fig. **192**

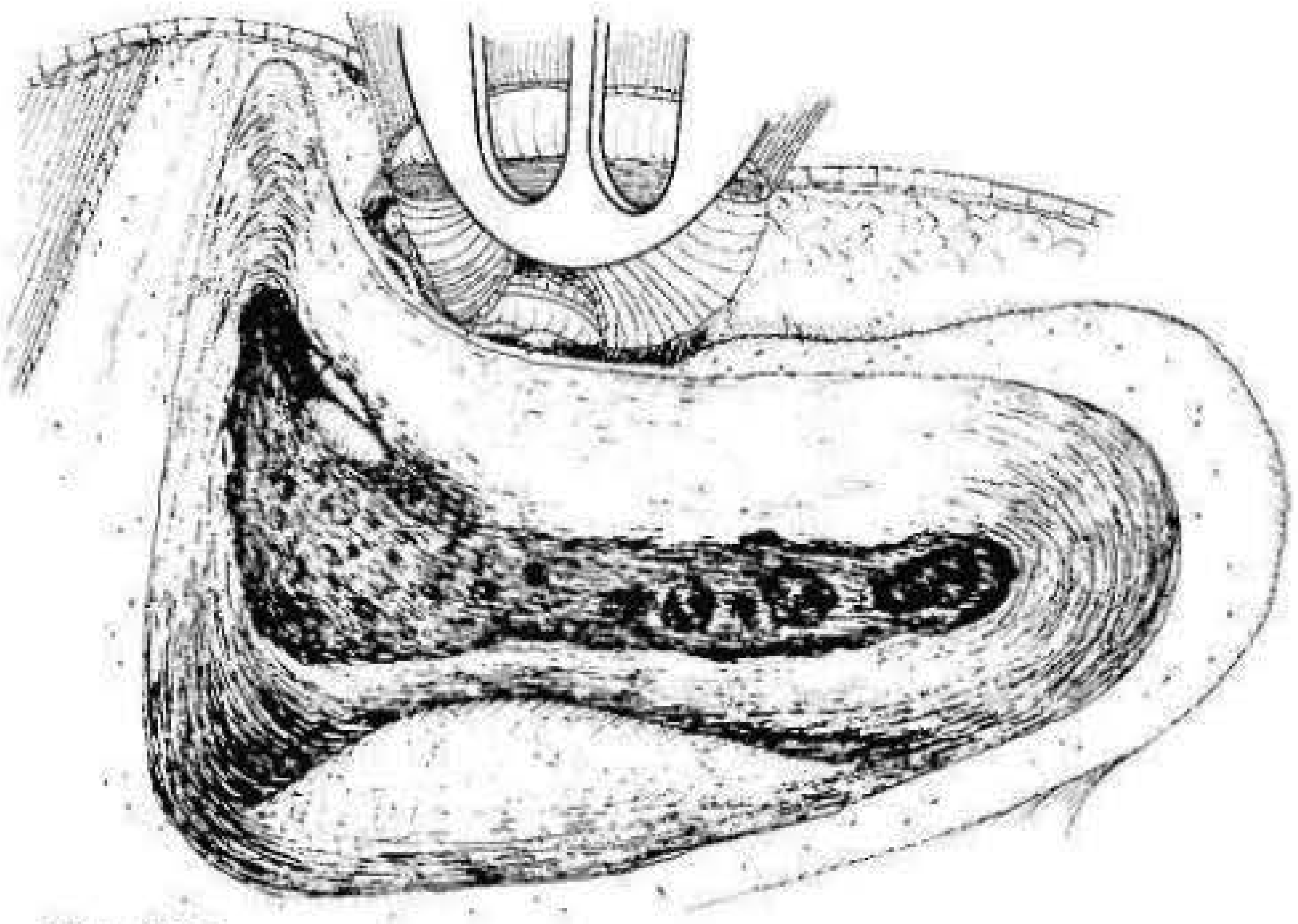


Fig. **193**

Fig. **191** The bone along the tegmen antri is removed using a diamond burr. The access to the antrum is widened, and drilling along the posterior bony ear canal wall takes place, thinning the bone

Fig. **192** The mastoid air cells are exenterated from the antrum, following the posterior fossa dura plate toward the tip of the mastoid

Fig. **193** After further drilling and thinning of the bony ear canal wall, and after rotating the operating table away from the surgeon, the head of the malleus, the incus body, and the lateral semicircular canal become visible a thick Körner's septum, a small cutting burr of about 2.0 mm is placed near the most posterior air cell of the Körner's septum, and the bone of the septum is drilled in an anterosuperior direction along the tegmen antri, or in a posteroinferior direction along the posterior fossa dura bony plate (Fig. **194**). Through careful drilling and widening of the initial opening while drilling in the same direction, the antrum is eventually reached. Drilling along the tegmen antri, there are no structures that can be damaged, because the superior petrosal sinus lies far posterior, and the superior semicircular canal is at a deeper level on the medial side of the antrum (Fig. **194**), while the lateral semicircular canal is anterior. While drilling along the tegmen antri, it is only the middle fossa dura that has to be attended to (Fig. **195**). After the superior and posterior walls of the antrum have been established, drilling of the lateral wall towards the ear canal exposes the malleus and the incus, as well as the lateral semicircular canal (Fig. **196**).

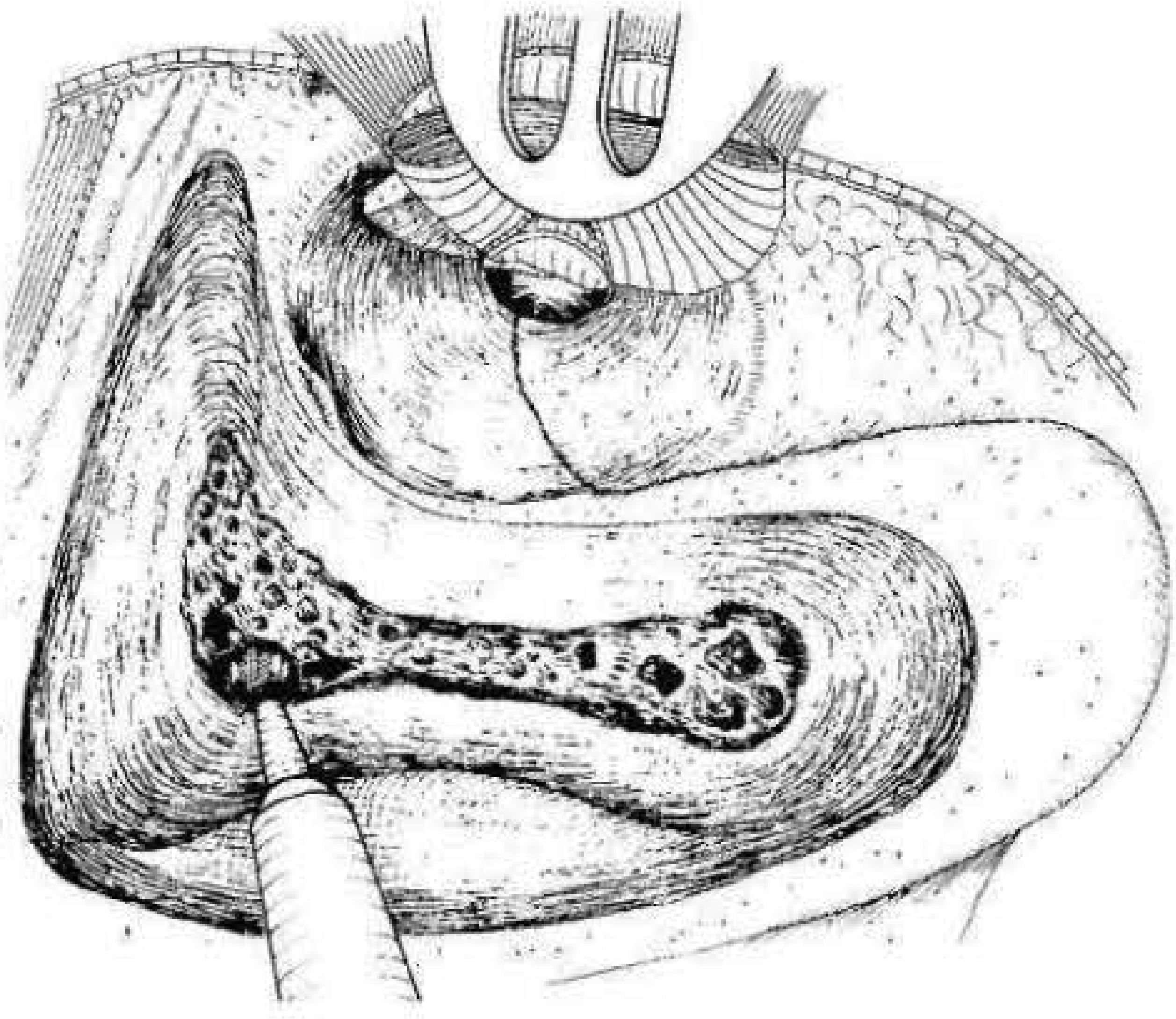


Fig. **194** **Entering the antrum in a case with little pneumatization and a thick Körner's septum**. A sharp drill is following a cell either in a superior or posterior direction

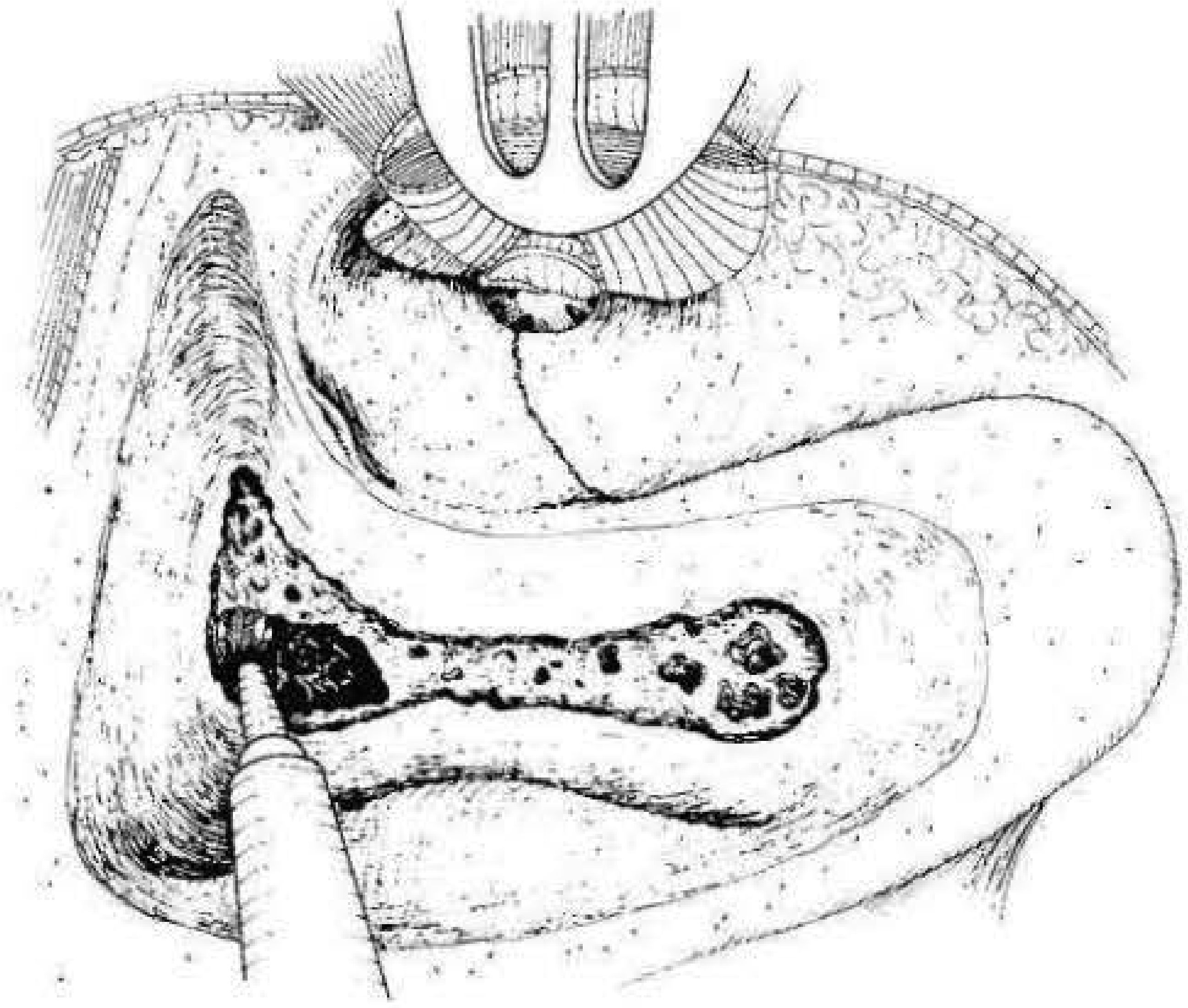


Fig. **195** The Körner's septum is removed posteriorly, exposing the Posterior part of the antrum, and further removal of the Kömer's septum takes place along the tegmen antri

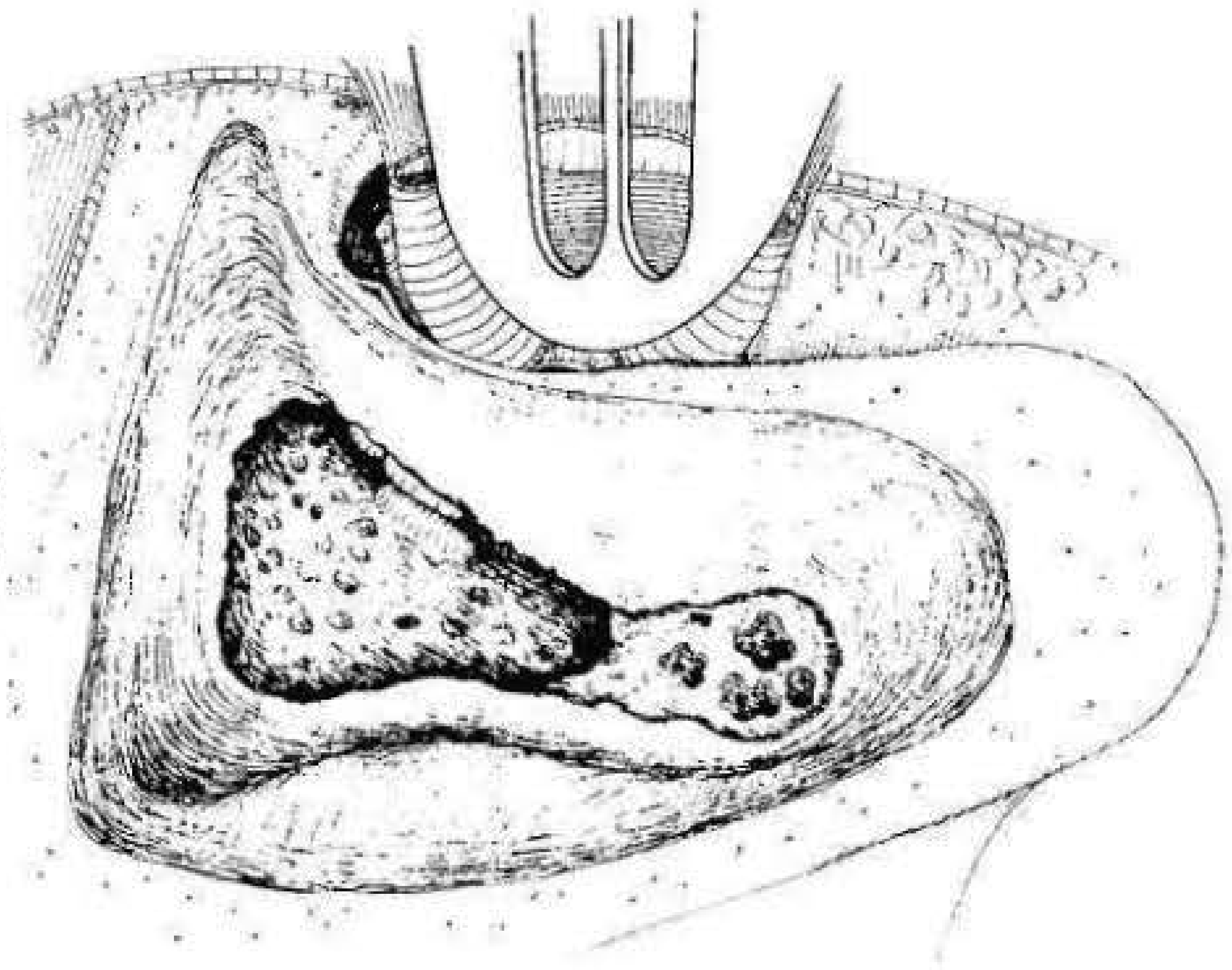


Fig. **196** After removal of the lateral wall of the antrum and extensive thinning of the bony ear canal, and after rotating the operating table away from the surgeon, the incus body, the malleus head, and the lateral semicircular canal are exposed

Exposure of the Sinodural Angle

After the antrum has been widely opened, the lateral semicircular canal located, and the medial wall of the antrum established, the remaining cells of the sinodural angle can be exenterated. This can be performed by "outside-inside" or "without–within" drilling using a sharp burr to carefully widen the sinodural angle, paging attention to the middle fossa dura plate and the sigmoid sinus bony plate. The exenteration of the sinodural angle cells can also be performed by "inside–outside" drilling, placing a cutting burr in the small cells at the medial antrum wall and gradually moving the drill outward (Fig. **197**). By performing this procedure once or twice, the cells are exenterated and the walls smoothed. Sometimes small cells occupy the sinodural angle; they can be removed using a small diamond burr (Fig. **198**). With careful drilling, damage to the middle fossa or posterior fossa dura can easily be avoided. In chronic middle ear disease, including cholesteatoma, the superior petrosal sinus is very rarely exposed, and the cholesteatoma does not usually extend as deep as the bony sulcus of the petrosal sinus.

Bleeding from the Emissary Vein and Superior Petrosal Sinus

The emissary vein of Citelli is located far posterolaterally, deep in the sinodural angle (Figs. **65**, **66**), and it can cause disturbing bleeding during drilling in this region. The beginner may be afraid of tearing the superior petrosal or sigmoid sinus, but the vein can fairly easily be electrocoagulated or occluded with bone wax, as described for the emissary vein of Santorini in Figure **177**. The bleeding from the bone can also be arrested with bone wax or by using the diamond burr; using a low speed with gentle pressure, the vein is occluded with bone dust. Bleeding from the emissary vein at its entrance into the sinus can be coagulated using curved bipolar forceps, as showed in Figure **177b**, or it can be covered with a piece of Surgicel (Fig. **175**). With a more extensive tear, a larger piece of Surgicel can be used for an external obliteration (Fig. **177**). Small pieces of Surgicel are *not* used, since embolization can occur.

Bleeding from the superior petrosal sinus posterolaterally in the sinodural angle rarely occurs, because the sinus enters the sigmoid sinus on its posterior surface (Figs. **66, 67**). In this region, the superior petrosal sinus lies in the depths of the sinodural angle in a sulcus. The superior petrosal sinus is therefore, in contrast to the sigmoid sinus, hardly exposed in cortical mastoidectomy. In rare cases with extension of the cholesteatoma from the antrum to the sinodural angle (Fig. **199**), the superior petrosal sinus may be exposed. In such cases, the middle and posterior fossa dura are also exposed by cholesteatoma. With careful dissection, the cholesteatoma

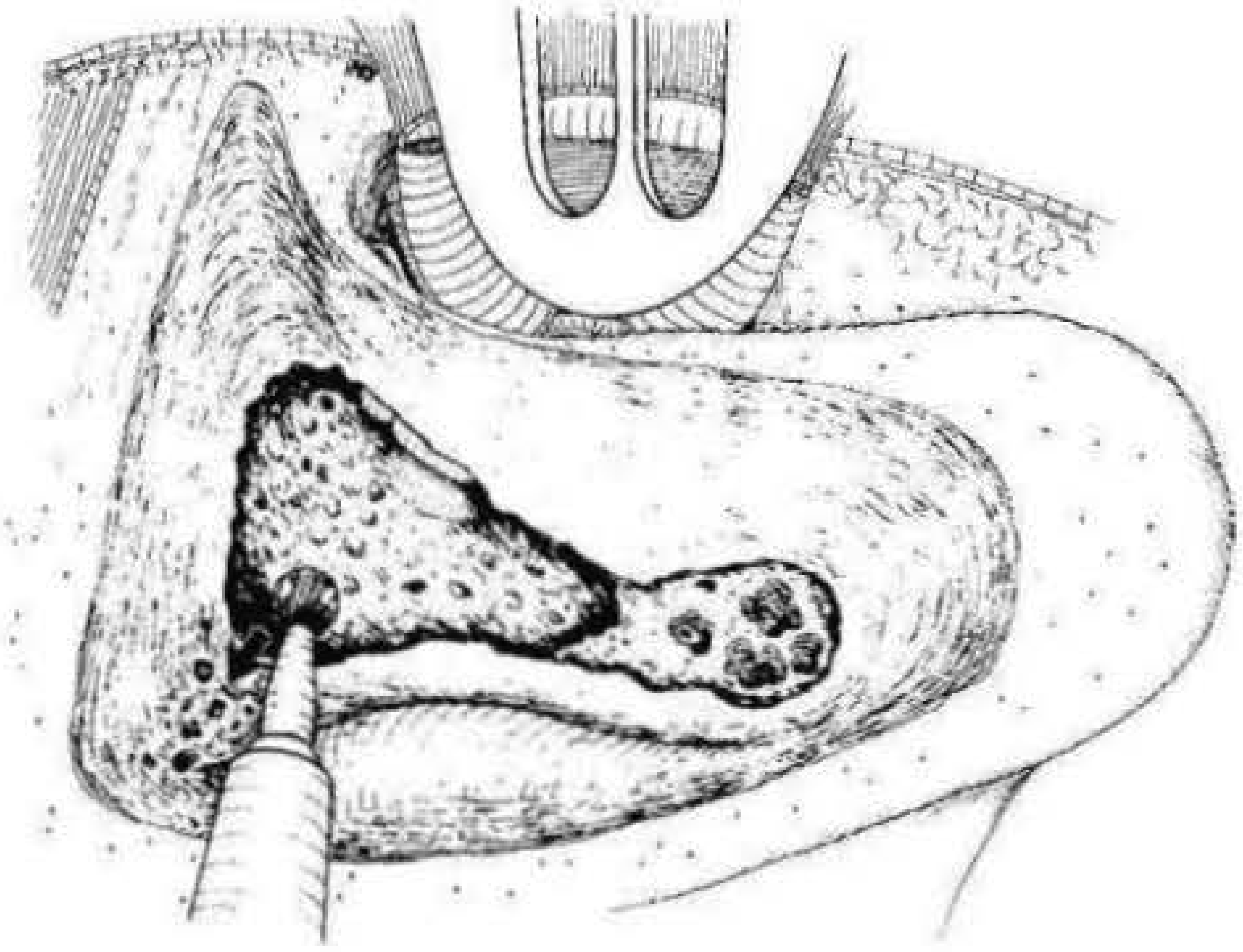


Fig. **197** **Exenteration of the cells from the sinodural angle.** A sharp burr is placed posteriorly deep in the antrum, and gently moved outward within the sinodural angle while rotating. The cells in the sinodural angle are opened and the septa are gradually removed.

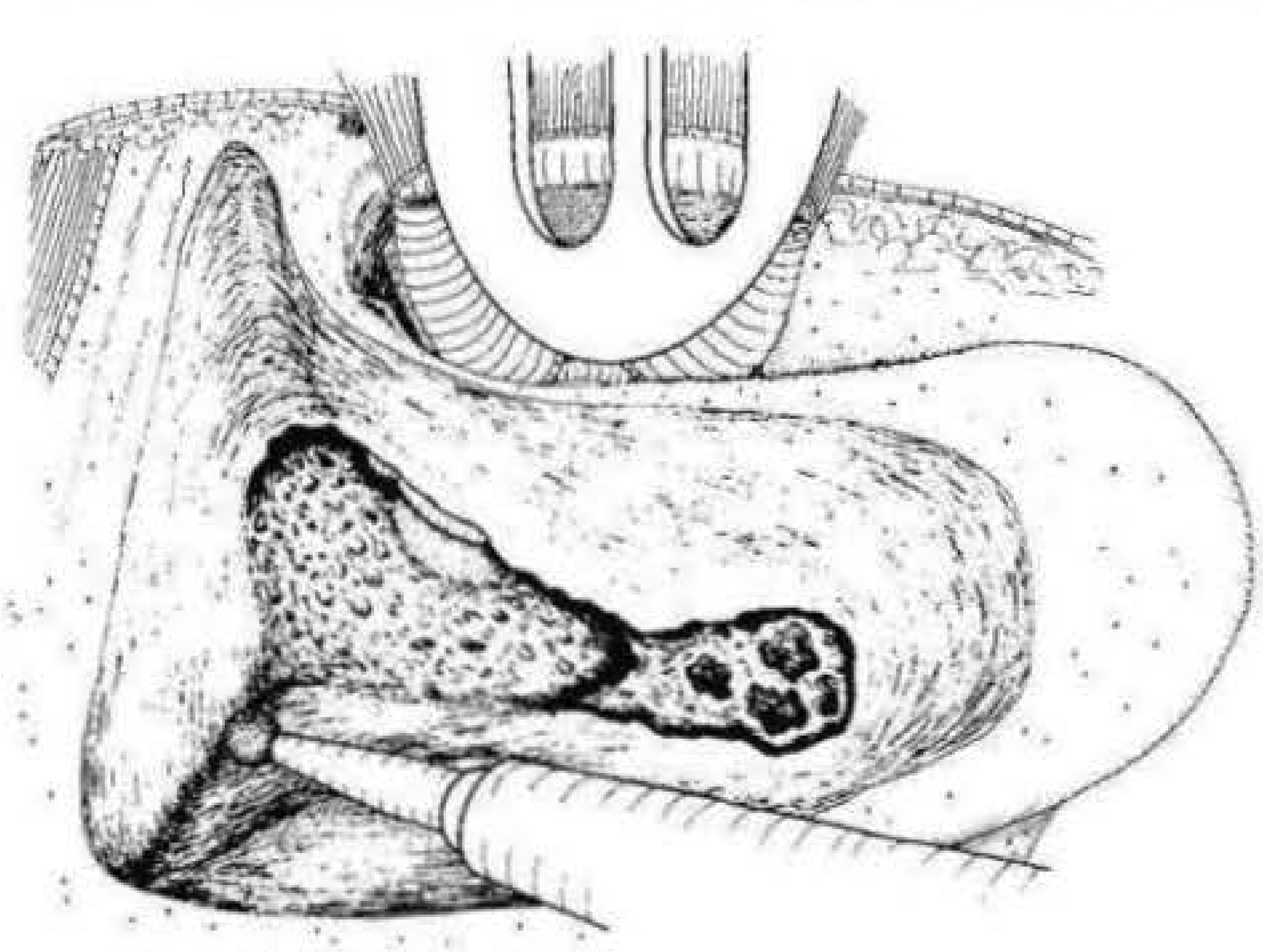


Fig. **198** Further smoothing of the bony plate within the sinodural angle using a small diamond drill.

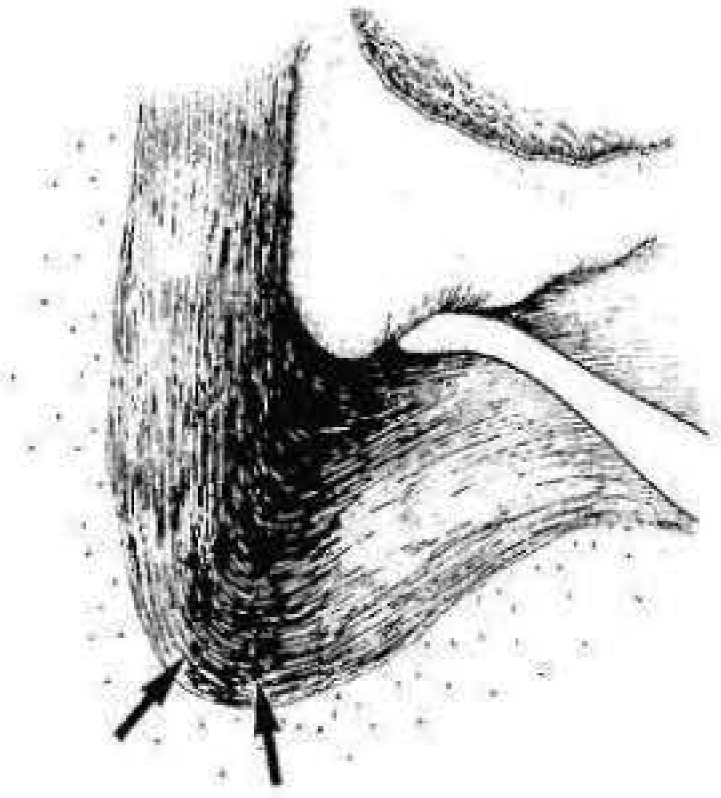


Fig. **199** Elevation of the cholesteatoma matrix from the sinodural angle. Arrows indicate the openings of the emissary vein of Citelli.

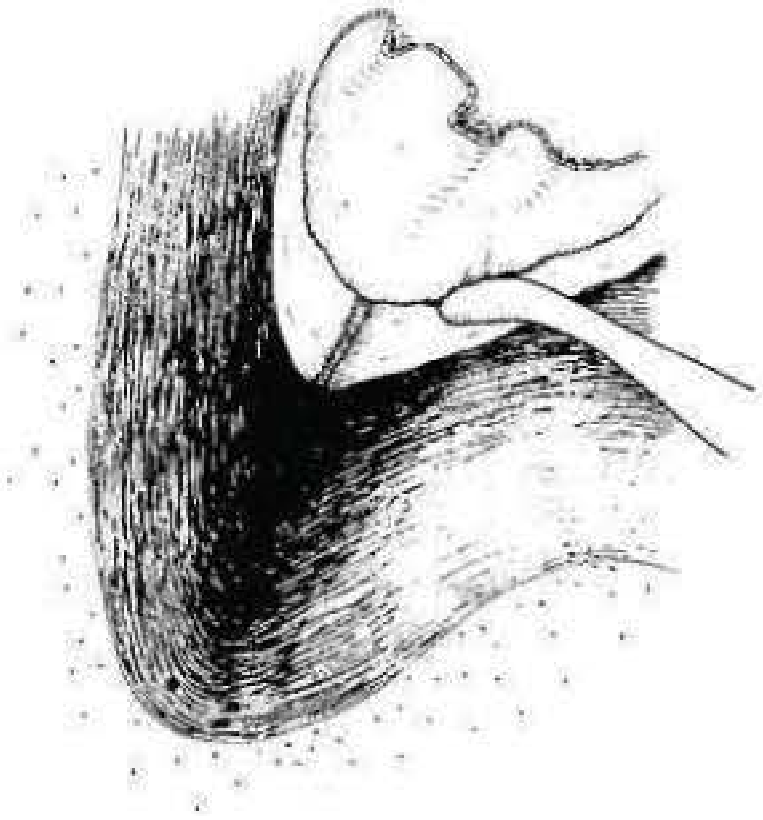


Fig. **200** The middle and posterior fossa dura, as well as the superior petrosal sinus, are exposed by cholesteatoma.

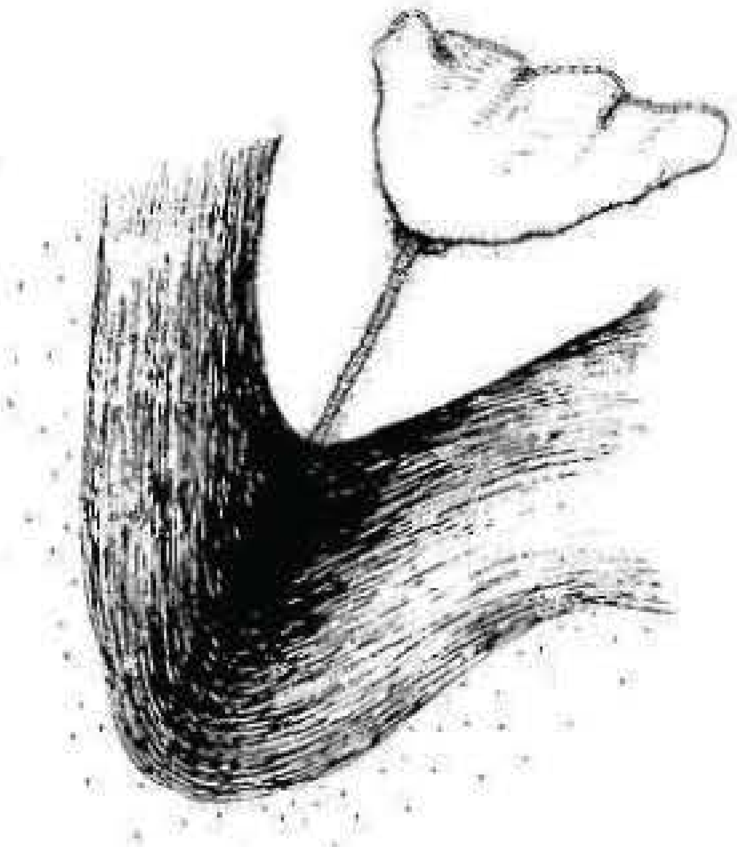


Fig. **201** The cholesteatoma matrix is elevated from the sinodural angle down to the perilabyrinthine space,

matrix can be elevated in toto from the sinus using **a** Freer's rougine (Fig. **200**) and dissected as far as the perilabyrinthine space (Fig. **201**).

Exposure of the entire superior petrosal sinus always takes place in translabyrinthine surgery, and sometimes in mastoidectomy as well as in some other types of skull base surgery procedures. Bleeding from the petrosal sinus can occur here.

Limited bleeding from the petrosal sinus is usually controlled using bipolar or monopolar cautery. The bipolar forceps coagulates the sinus wall together. The monopolar cautery is more effective than the bipolar one. Sometimes the sinus is filled with Surgicel during coagulation. If cautery is not effective, a small piece of Surgicel can be placed on the sinus and pressure applied to stabilize it during further manipulation.

In more extensive bleeding, when cautery or external obliteration proves ineffective, the superior petrosal sinus has to be ligated on both the lateral and medial sides of the laceration. Ligation of the superior petrosal sinus near the sigmoid sinus is performed with neurosurgical clips inserted on either side of the laceration. Laceration further medially can be treated by internal obliteration of the lumen using Surgicel and coagulation. The Surgicel occludes the proximal lumen, and the distal lumen toward the sigmoid sinus is occluded by coagulation.

Bleeding from the superior petrosal sinus can also be controlled by placing two 6–0 silk ligatures around the sinus (Fig. **202**). Small holes through the dura are made using a hook on each side of the sinus; the suture is passed through these holes and around the sinus.

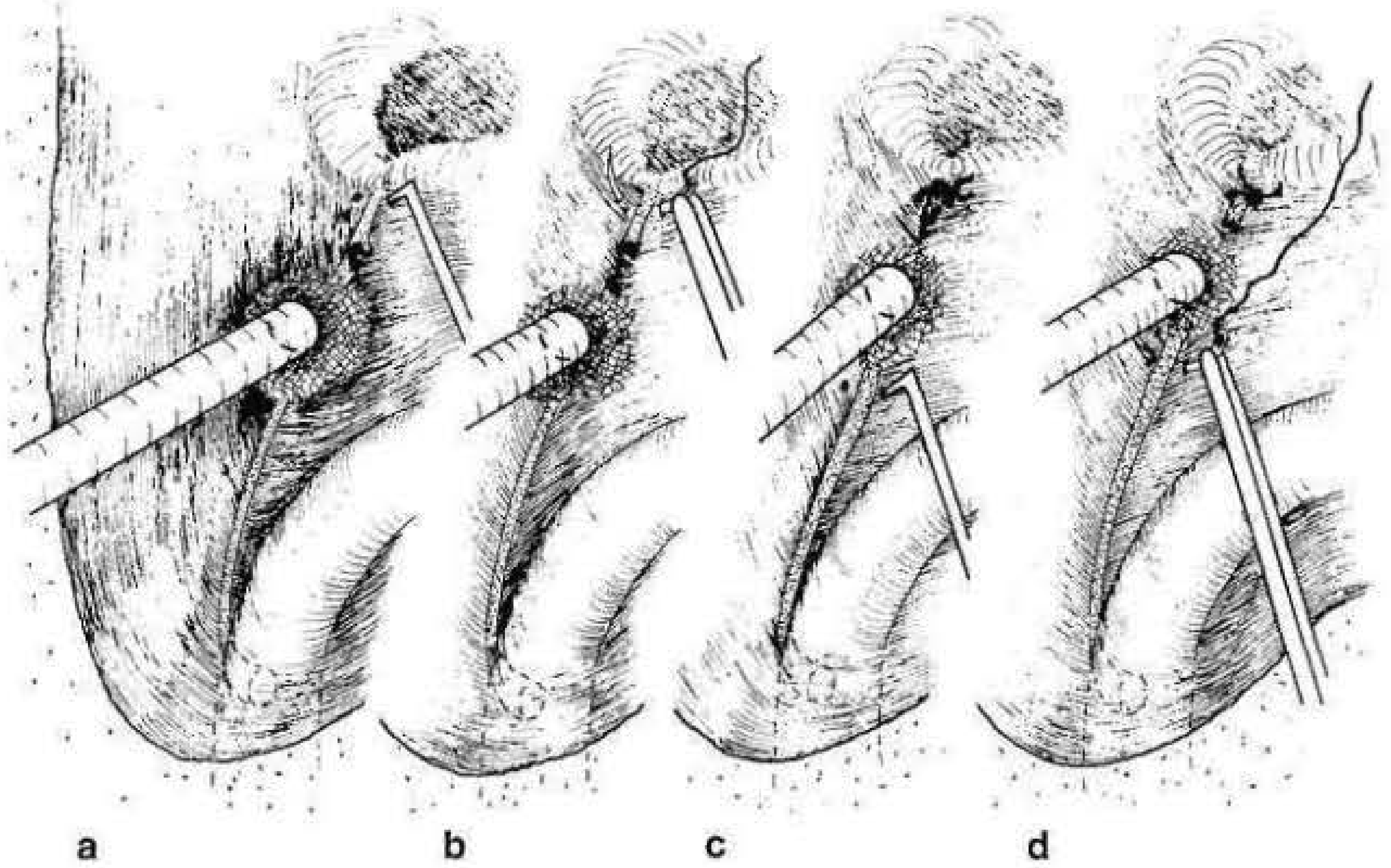


Fig. **202** **Ligation of the superior petrosal sinus.**
a The proximal part is compressed by Surgicel, and the compression is held in place with a suction tube. In the distal part, a hole is made in the dura on both sides of the sinus with a hook.
b A needle is brought around the sinus.
c The distal part is ligated with a 3–0 silk suture. The Surgicel is moved distally, and new holes are made proximally to the Surgicel on both sides of the sinus.
d The sinus is ligated proximally

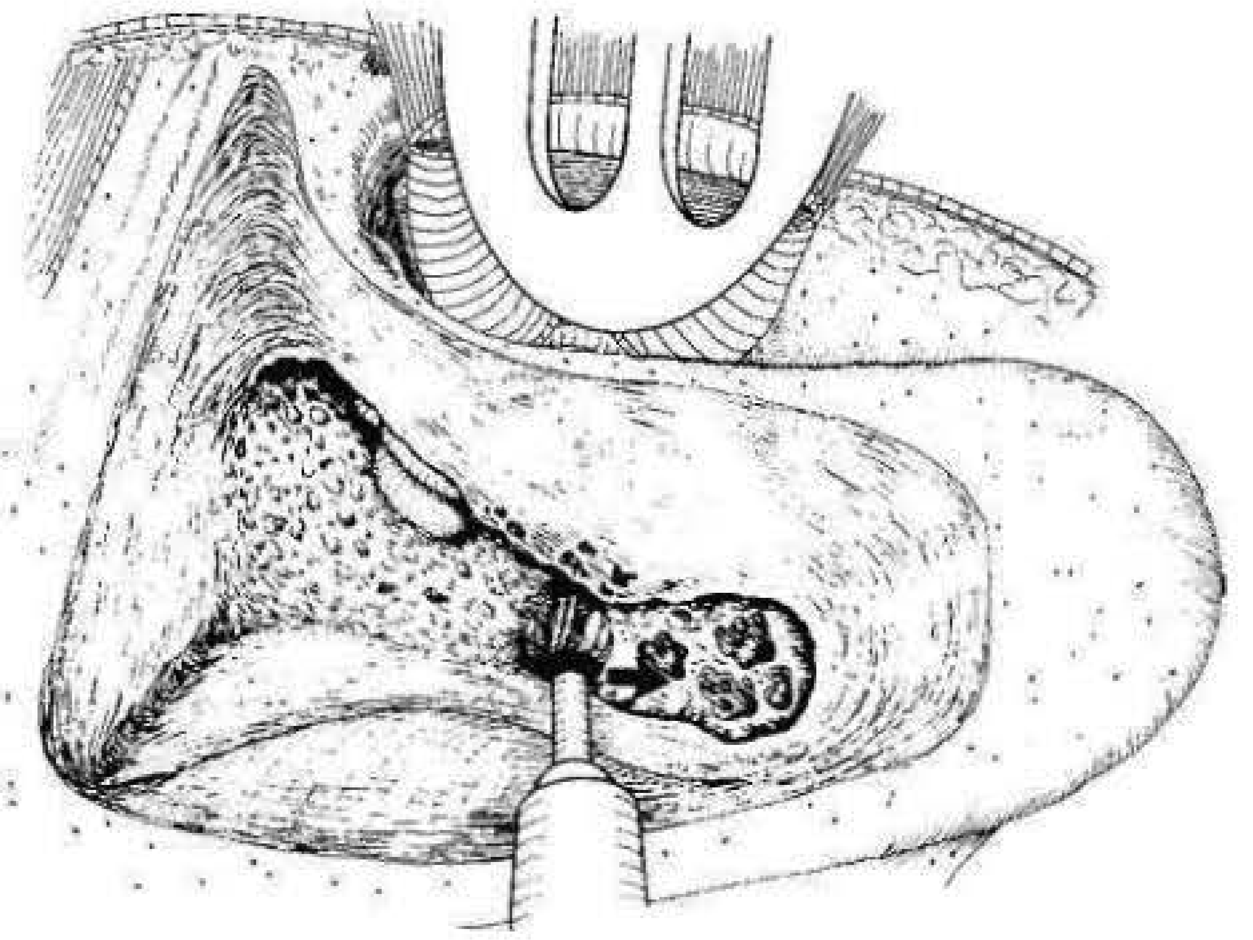


Fig. **203** **Exenteration of the mastoid tip cells** from the mastoid antrum. With a relatively large cutting burr, the cells are exenterated along the posterior fossa dura, with the drill being moved gently toward the tip of the mastoid process (arrow)

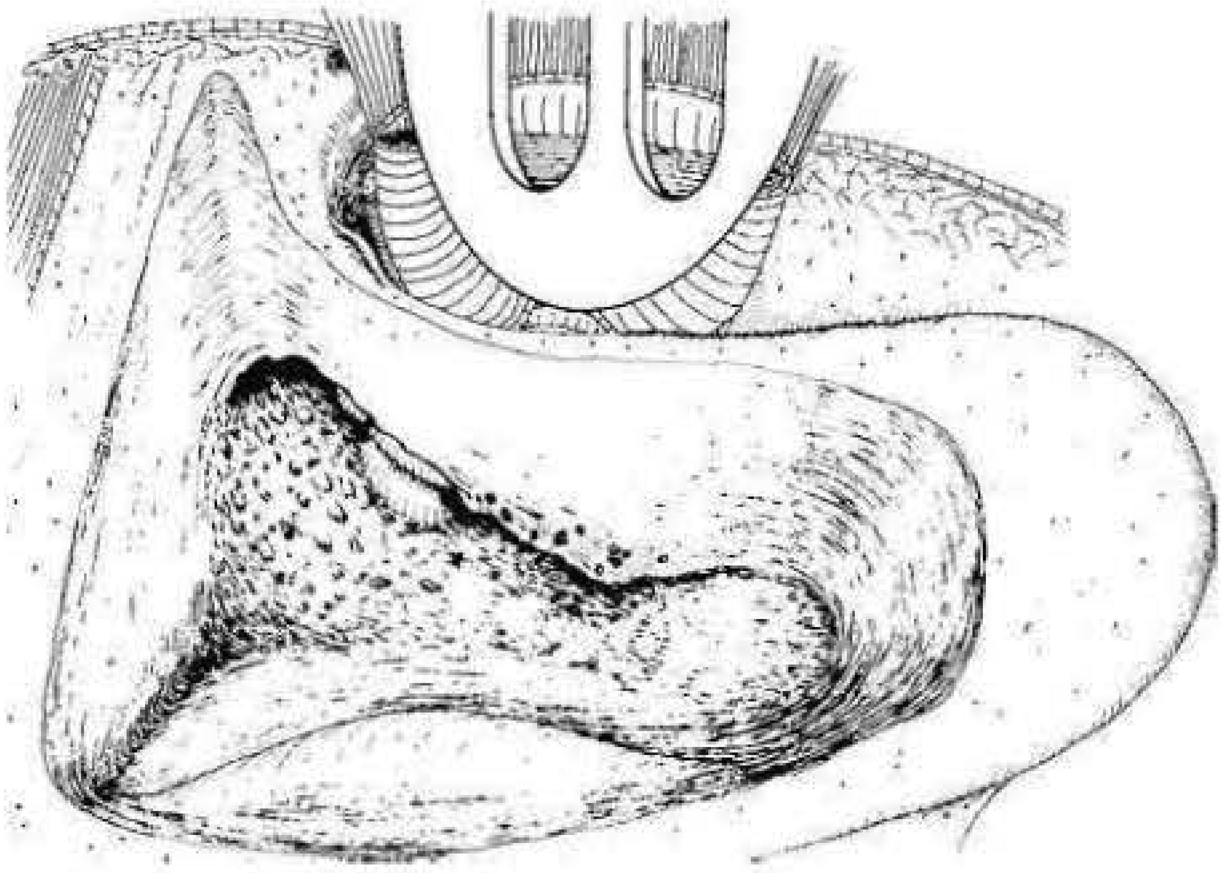


Fig. **204** Further smoothing of the wall of the mastoid tip in a case with little pneumatization

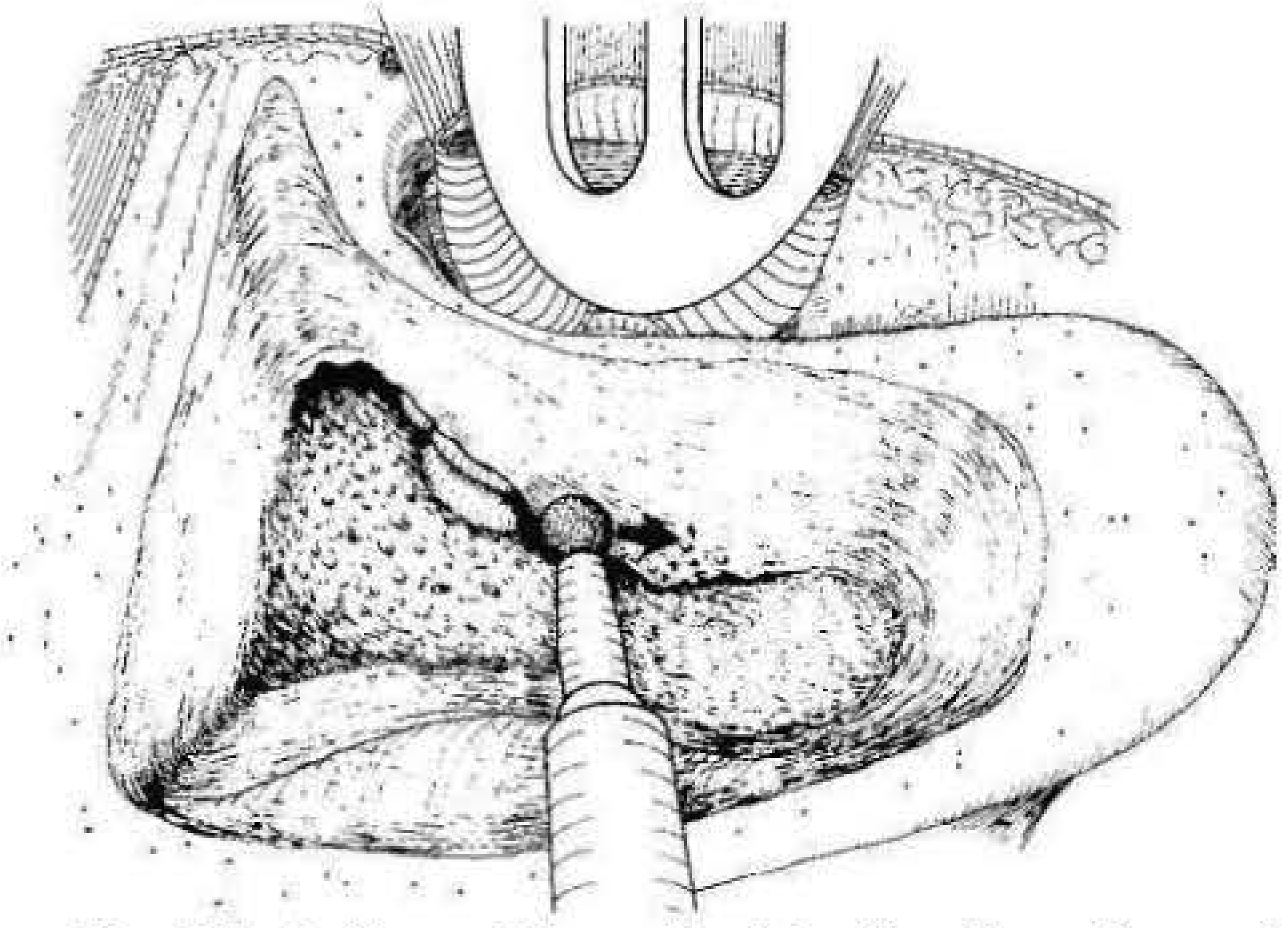


Fig. **205** Drilling of the perifacial cells with a diamond drill, starting inferior to the posterior end of the short process of the incus, and moving the drill gently in an inferior direction (arrow) along the course of the facial nerve

As mentioned earlier, bleeding from the sinus is extremely rare in mastoidectomy for middle ear disease. During translabyrinthine surgery, we have had several incidents of bleeding from the sinus, which could always be stopped by external coagulation or external packing. We have never had to ligate or clip the sinus completely. Complete ligation of the petrosal sinus does not have any attendant sequelae.

Exenterating the Mastoid Tip Cells

The size and extent of the mastoid air cells varies considerably. In cases with limited pneumatization, there are usually no cells in the matoid tip, or they are very small and it is not necessary to follow them to the tip in order to exenterate them. With a relatively large burr, the cells are exenterated along the posterior fossa dura toward the mastoid tip (Fig. **203**). Through careful drilling in this region, the cells are followed towards the tip, and no major cell septa are left. The resulting small cavity which, with limited pneumatization, may just be a short prolongation of the antrum toward the mastoid process, is then smoothed (Fig. **204**). After smoothing the mastoid tip posteriorly and posteroinferiorly, exenteration of the perifacial cells can be performed using a medium-sized diamond burr. Drilling starts at the fossa incudis and gradually continues in an inferior direction, carefully smoothing the walls of the small perifacial cells, which are gradually removed by proceeding gently in an inferior direction along the course of the vertical segment of the facial nerve (Fig. **205**). After further drilling of the sinus-facial angle cells, the perifacial cells are more or less exenterated, and the cavity is then smoothed (Fig. **206**).

In cases with extensive pneumatization (Figs. **189–193**), the mastoid cells continue far inferiorly toward the mastoid tip (Fig. **193**), and have to be removed. With continuous drilling, following the cells toward the tip of the mastoid process (Fig. **207**), the inferior part of the cavity becomes large (Fig. **208**). Using a diamond burr, the septa of the remaining cells can be drilled away and the mastoid tip smoothed. Finally, the perifacial cells are removed using a relatively large diamond burr (Fig. **209**), and the sinus facial angle is widened. The cavity is now smooth.

Sometimes the mastoid tip cells continue below the digastric crest (Fig. **210**) and have to be exenterated. This is most safely performed using a diamond burr and removing the cell septa, creating a large cavity inferiorly (Fig. **211**).

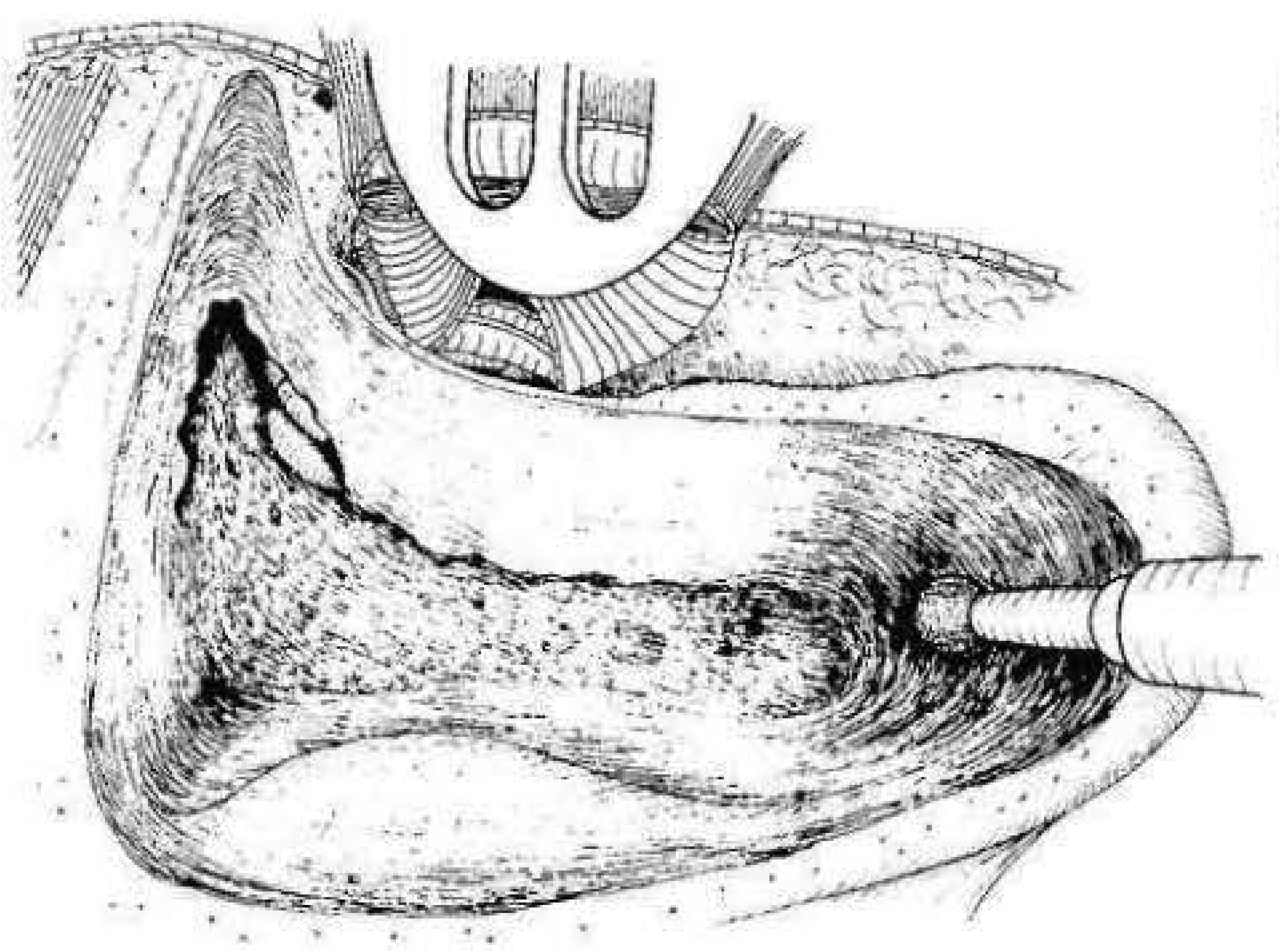


Fig. **206** The perifacial cells are more or less exenterated, and the cavity has been smoothed, in a case with little pneumatization. The simple mastoidectomy has been completed

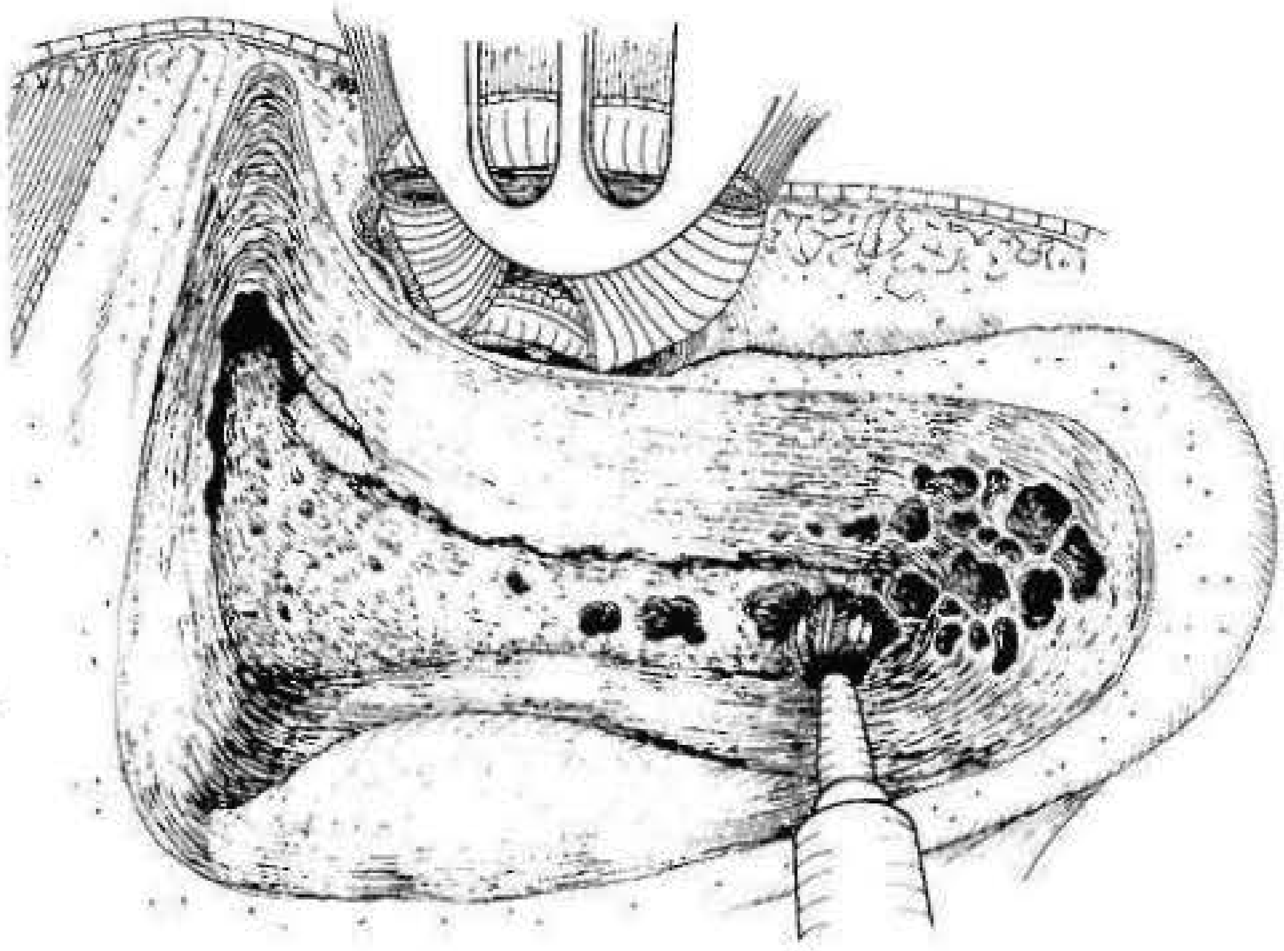


Fig. **207** In a case with extensive pneumatization, further cells at the tip of the mastoid process should be followed and exenterated by moving a sharp diamond drill along the posterior plate toward the tip

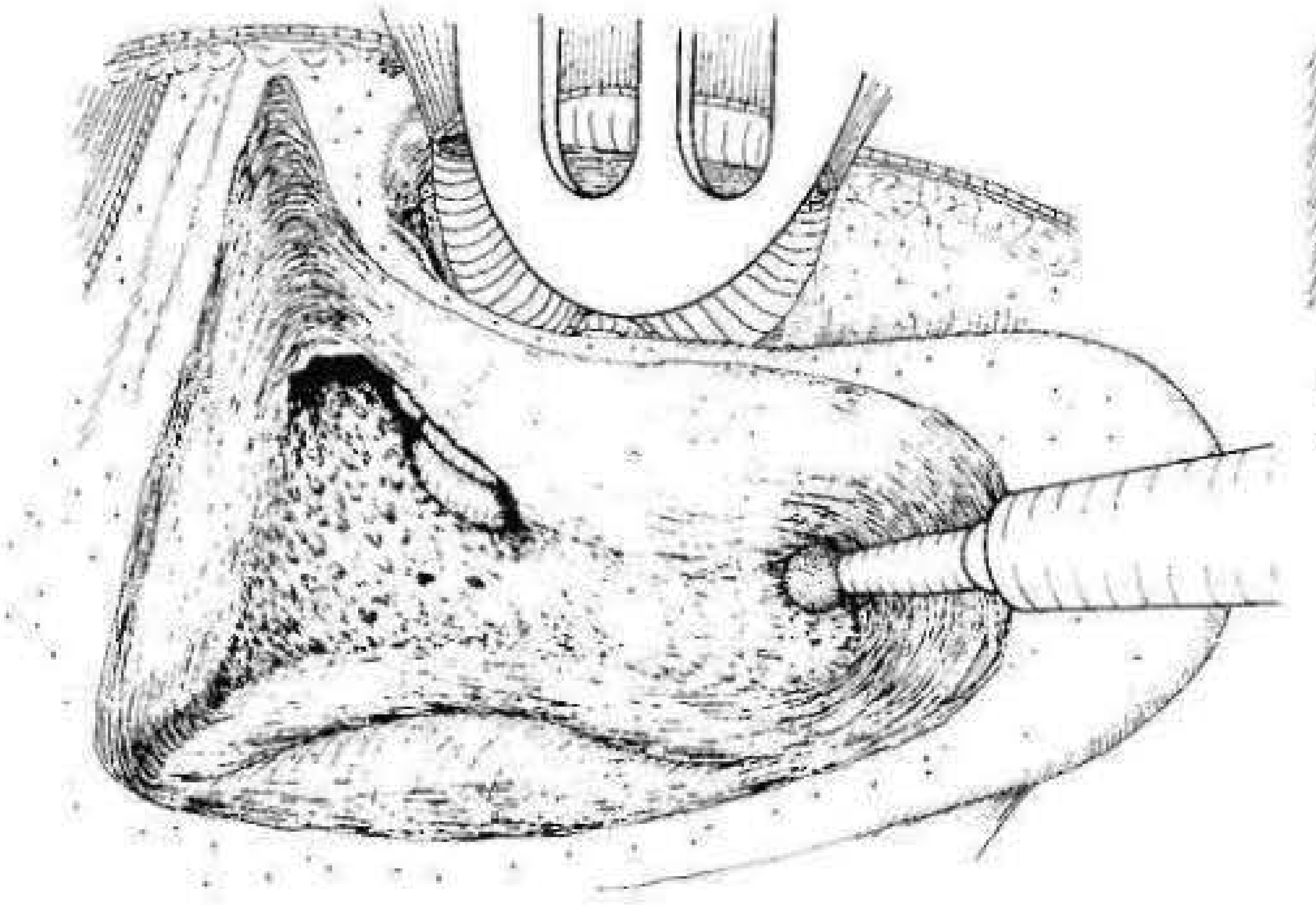


Fig. **208** The cells in the mastoid tip are exenterated and the tip wall is smoothed

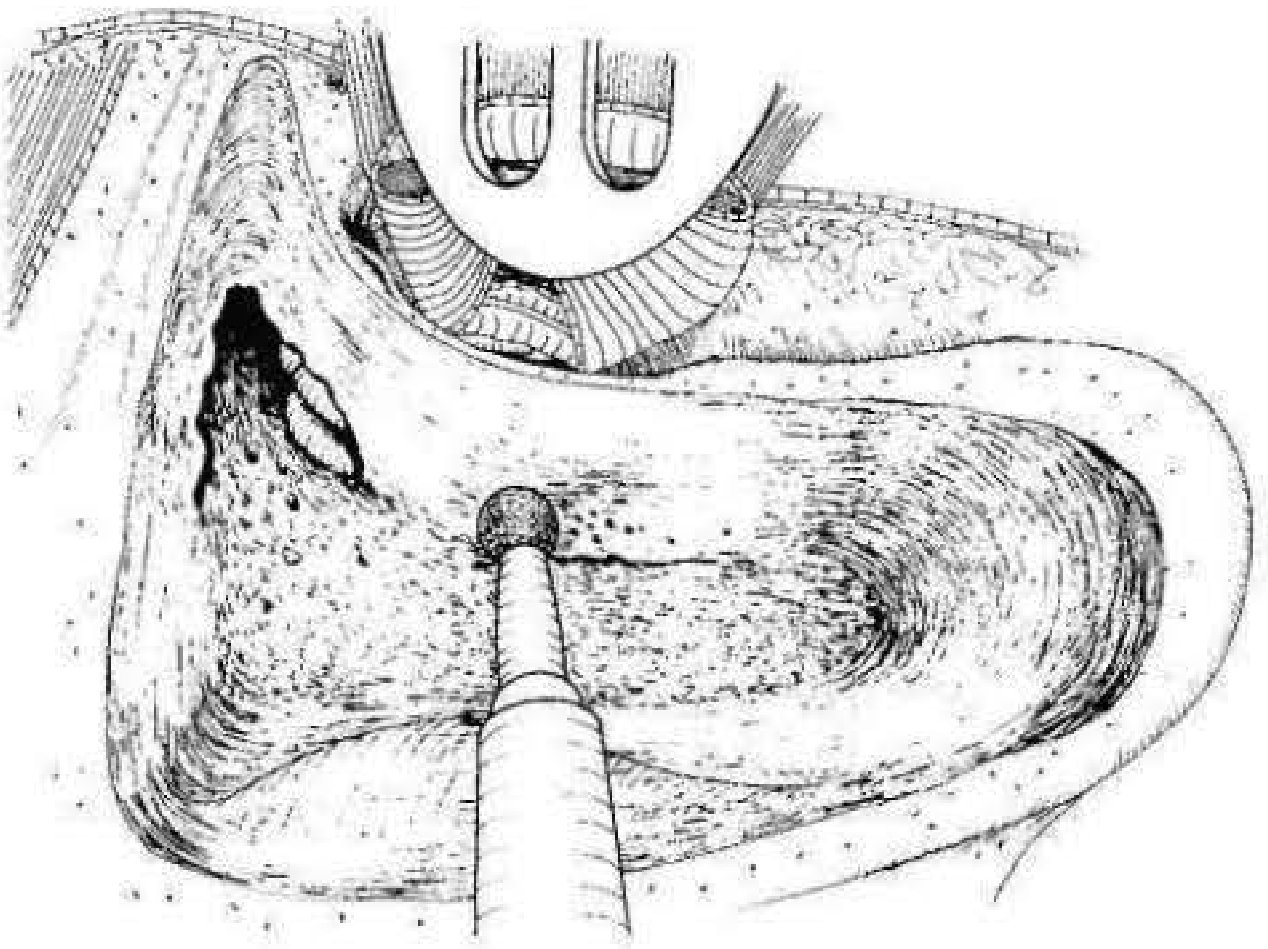


Fig. **209** The perifacial cells are being smoothed in a case with relatively large mastoid cells

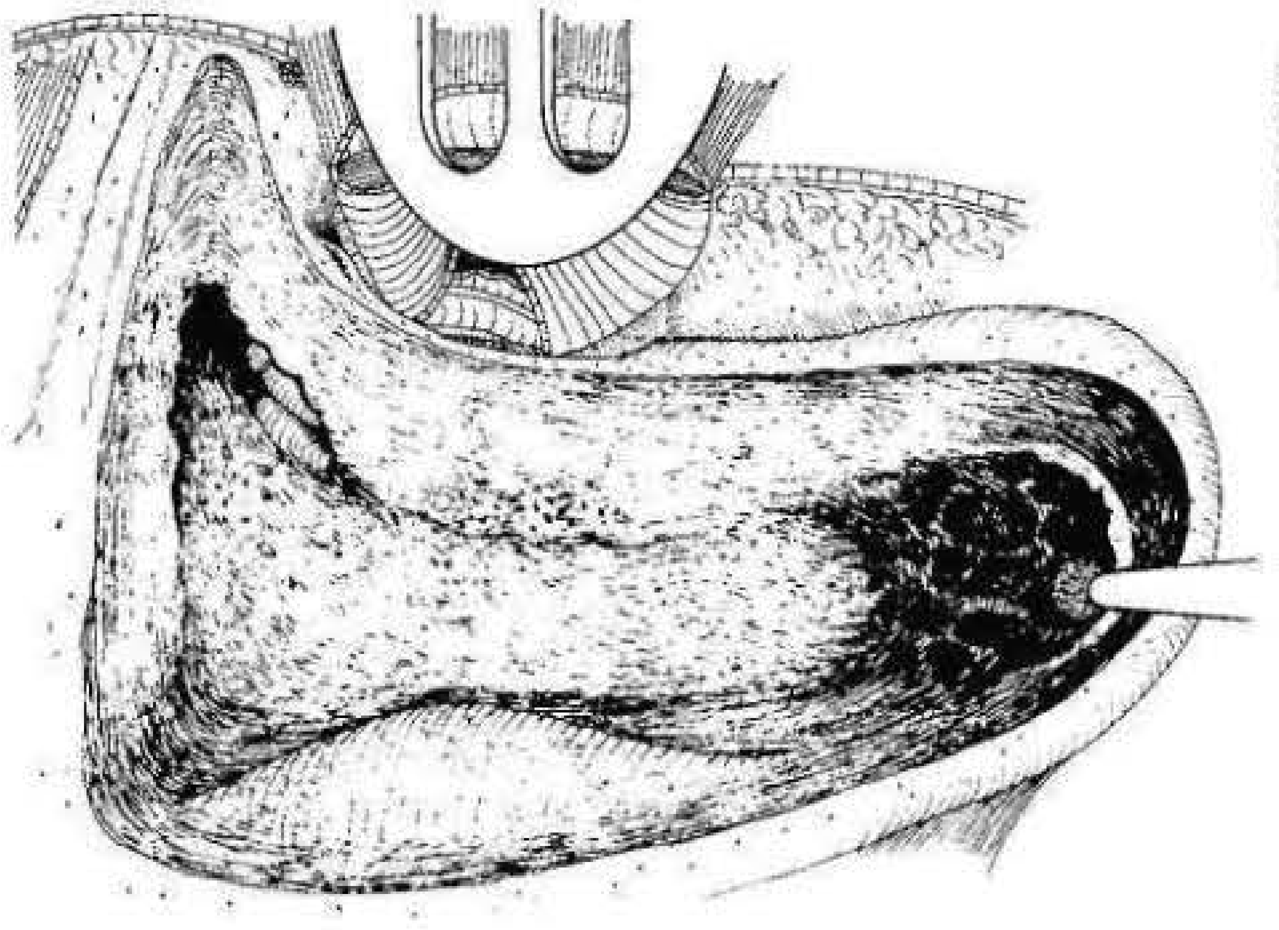


Fig. **210** A case with large, extensive mastoid cells continuing down under the digastric cells. The cells are removed using a diamond burr

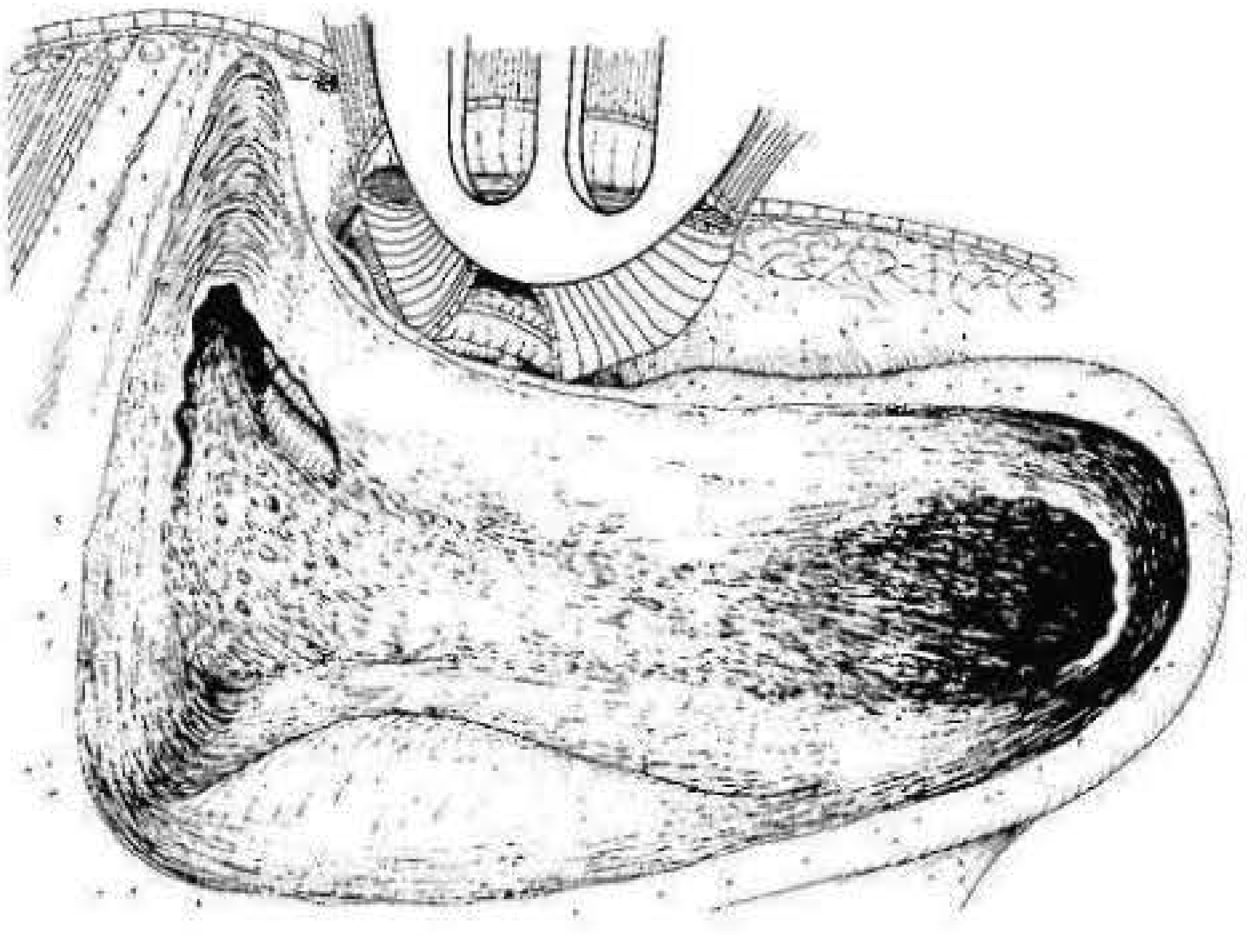


Fig. **211** Finally, the mastoid tip is cleaned, and the digastric crest becomes visible

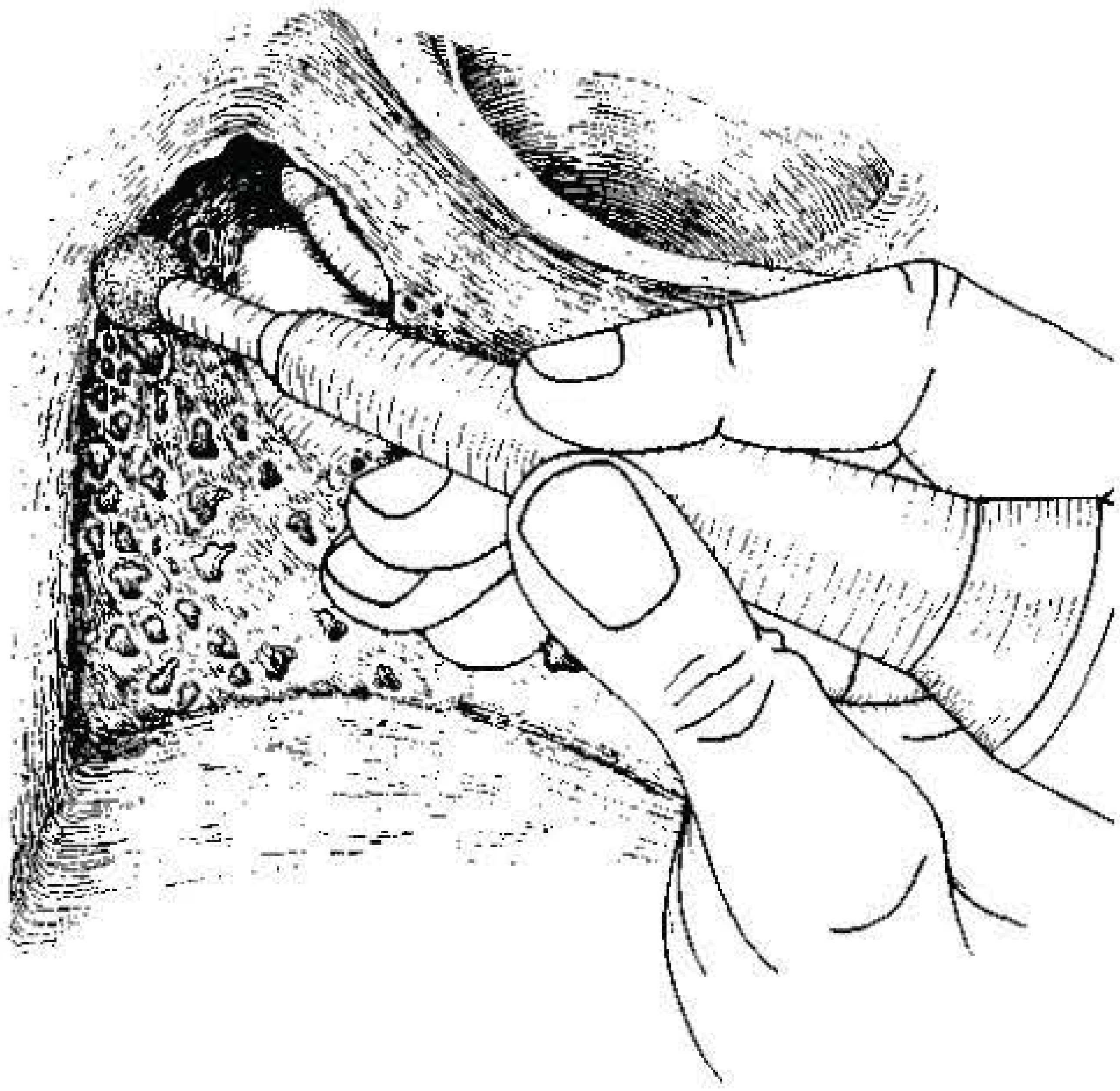


Fig. **212** **Exenteration of the perilabyrinthine air cells.** Using a diamond burr, the air cells of the tegmen antri and tegmen tympani are carefully removed, enlarging the distance between the lateral semicircular canal and the middle fossa dura plate

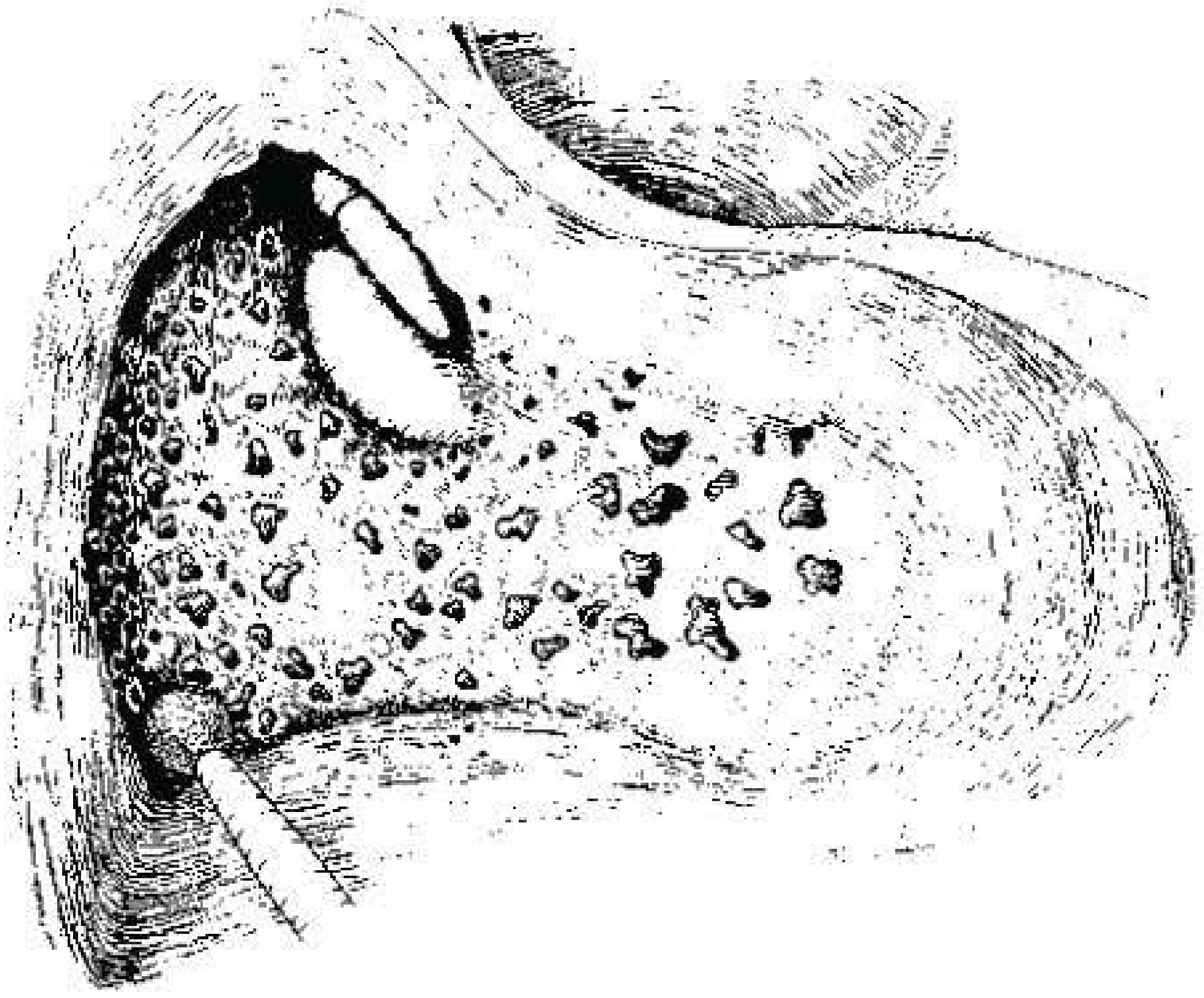


Fig. **213** The tegmental air cells have been exenterated, and the space between the lateral semicircular canal and the middle fossa dura plate has become larger. Exenteration continues posteriorly toward the sinodural angle. The contours of the superior semicircular canal are not yet visible

Exenterating the Perilabyrinthine Cells

The size and extent of the superior perilabyrinthine cells, the translabyrinthine cells, and the retrolabyrinthine and infralabyrinthine cells varies in relation to the degree of pneumatization.

In *sclerotic* temporal bones, there are hardly any perilabyrinthine cells. After removal of the cholesteatoma or the diseased mucosa, the medial wall of the antrum is more or less smooth, and very little drilling has to be performed to smooth the medial antrum wall completely. The resulting small cellular remnant, if clear of cholesteatoma, can easily be exenterated by drilling the septa with a diamond burr.

In ears with *extensive pneumatization,* the periantral cells cover the medial wall of the antrum and communicate widely with the perilabyrinthine cells, which continue along the middle and posterior fossa dura plate toward the petrous apex (see Chapter 3). If the pathology requires it, e. g., in cases of cholesteatoma or infected mucosa, the perilabyrinthine cells have to be exenterated.

After skeletonizing the tegmen antri down to the level of the lateral semicircular canal, further removal of the periantral cells of the medial wall of the antrum is performed using a small diamond burr, moving it along the middle fossa dura plate (Fig. **212**). The superior semicircular canal lies about 2 mm deeper, and as long as relatively large air cells are present, there is no risk of entering the canal. Drilling further along the tegmen antri, the cells become smaller, and the distance between the lateral semicircular canal and the tegmen increases (Fig. **213**). The air cell exenteration continues in the region between the superior and posterior semicircular canal and along the superior petrosal sinus.

Before one continues along the superior semicircular canal, the translabyrinthine cells can be exenterated (Fig. **214**). Using a small diamond burr, the largest translabyrinthine cell is further enlarged toward the periphery of the interlabyrinthine space. The subarcuate artery may bleed, but after further drilling the bleeding stops. After further drilling, the inner contours of the superior and posterior semicircular canals become visible (Fig. **215**), and further exenteration of the superior perilabyrinthine cells proceeds, using a small burr along the middle fossa dura plate. The outer contours of the superior and posterior semicircular canals slowly become visible (Fig. **216**), and drilling along the canals and between the superior canal wall and middle fossa dura plate continues until all cells are exenterated or free of gross pathology (Fig. **217**). Finally, the small cells at the junction of the superior and lateral semicircular canal and at the junction of the superior and posterior canals can be exenterated, as can the triangular region anterior to the lateral semicircular canal and superior to the posterior semicircular canal. The medial wall of the antrum and aditus ad antrum is now clear, and the wall has been completely smoothed (Fig. **218**).

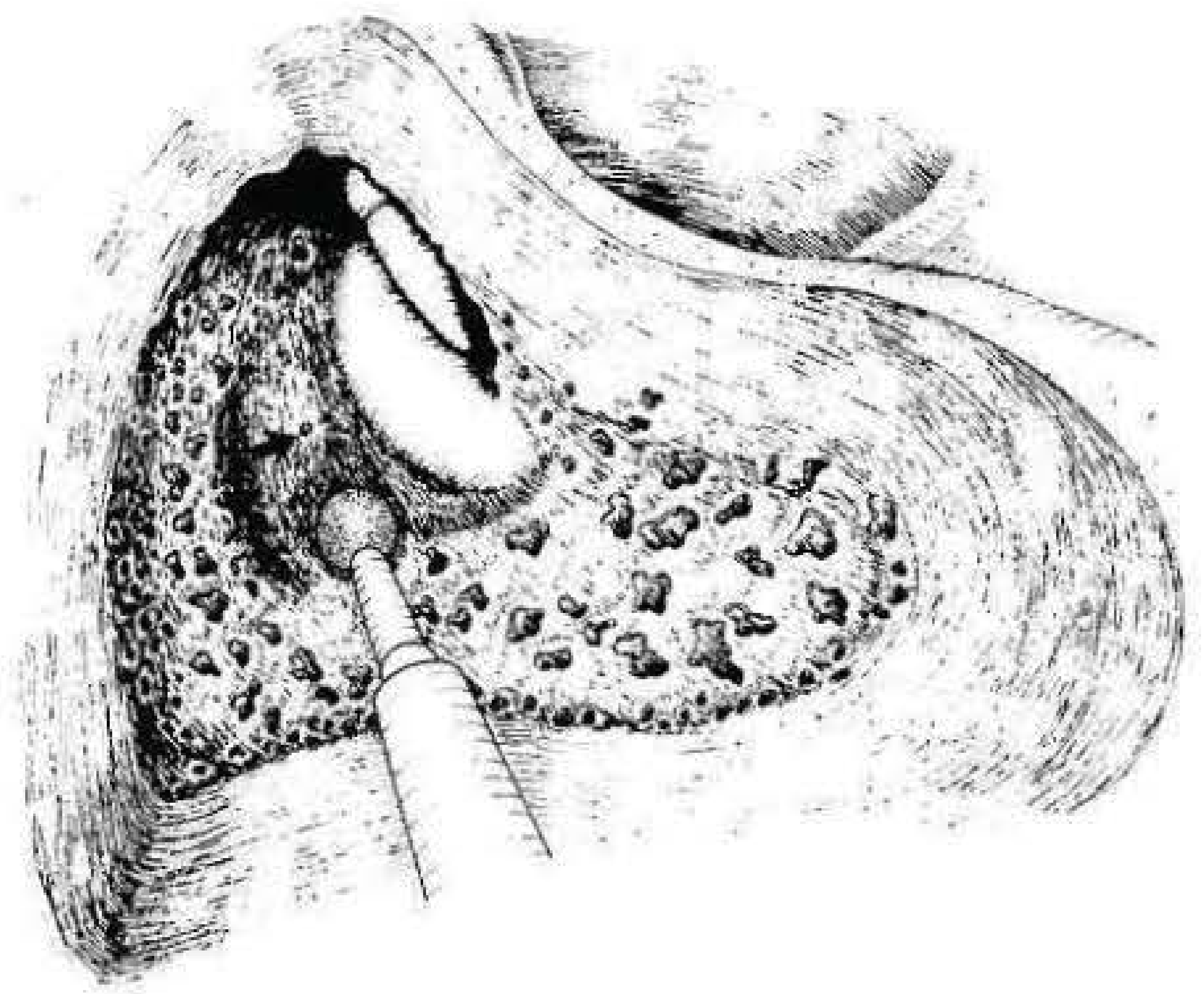


Fig. **214** **Exenteration of the translabyrinthine air cells**. The cells lying superior to the lateral semicircular canal are followed to the depth, and enlarged using a small diamond burr. The translabyrinthine space is enlarged, and the walls are smoothed while careful attention is paid to the inner contours of the superior and posterior semicircular canals. The subarcuate artery (arrow) is located; it may bleed

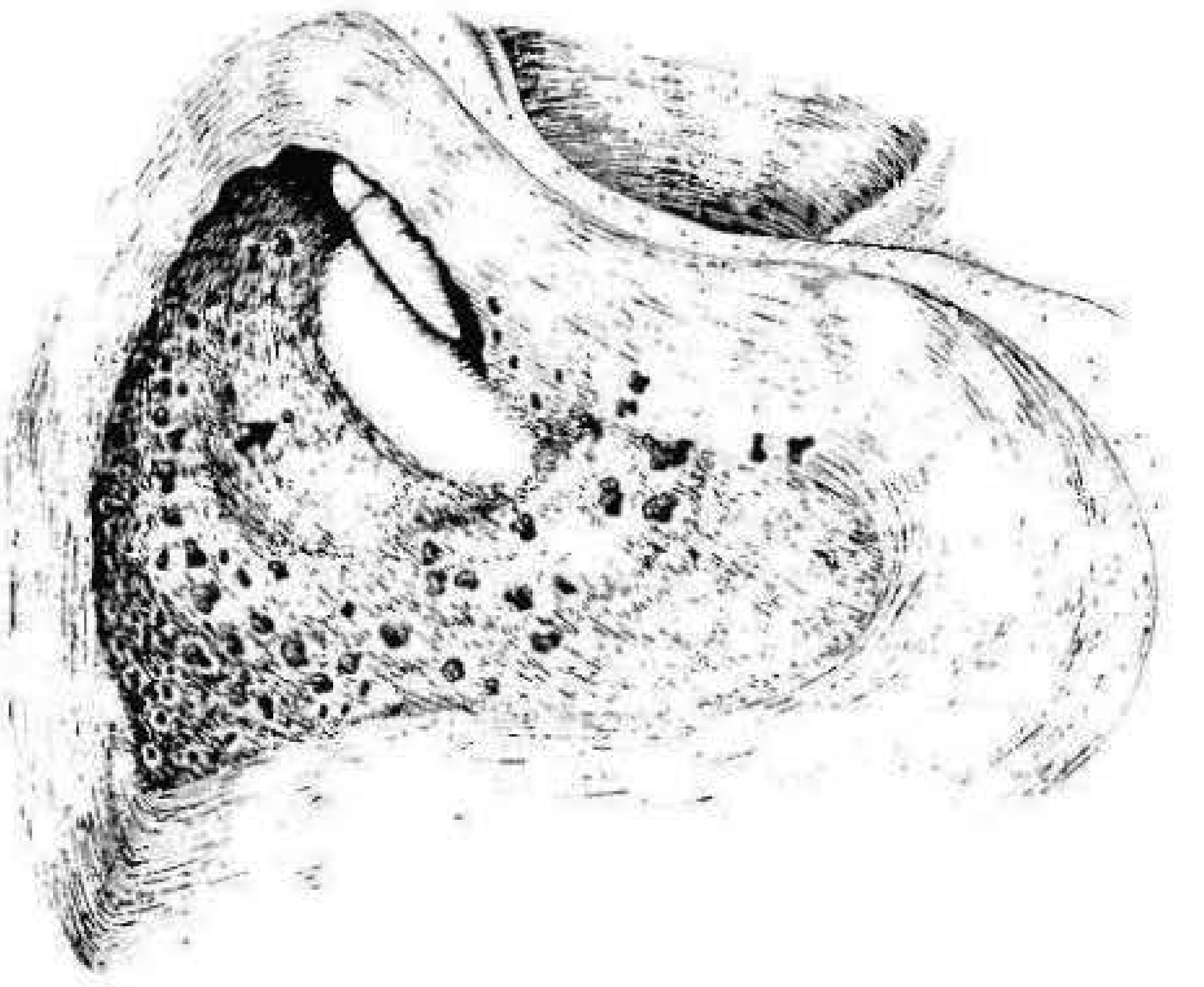


Fig. **215** The translabyrinthine air cells have been removed, the space between the three semicircular canals has been widened, and the inner contours of the superior and posterior canal are visible. The subarcuate artery is followed further (arrow)

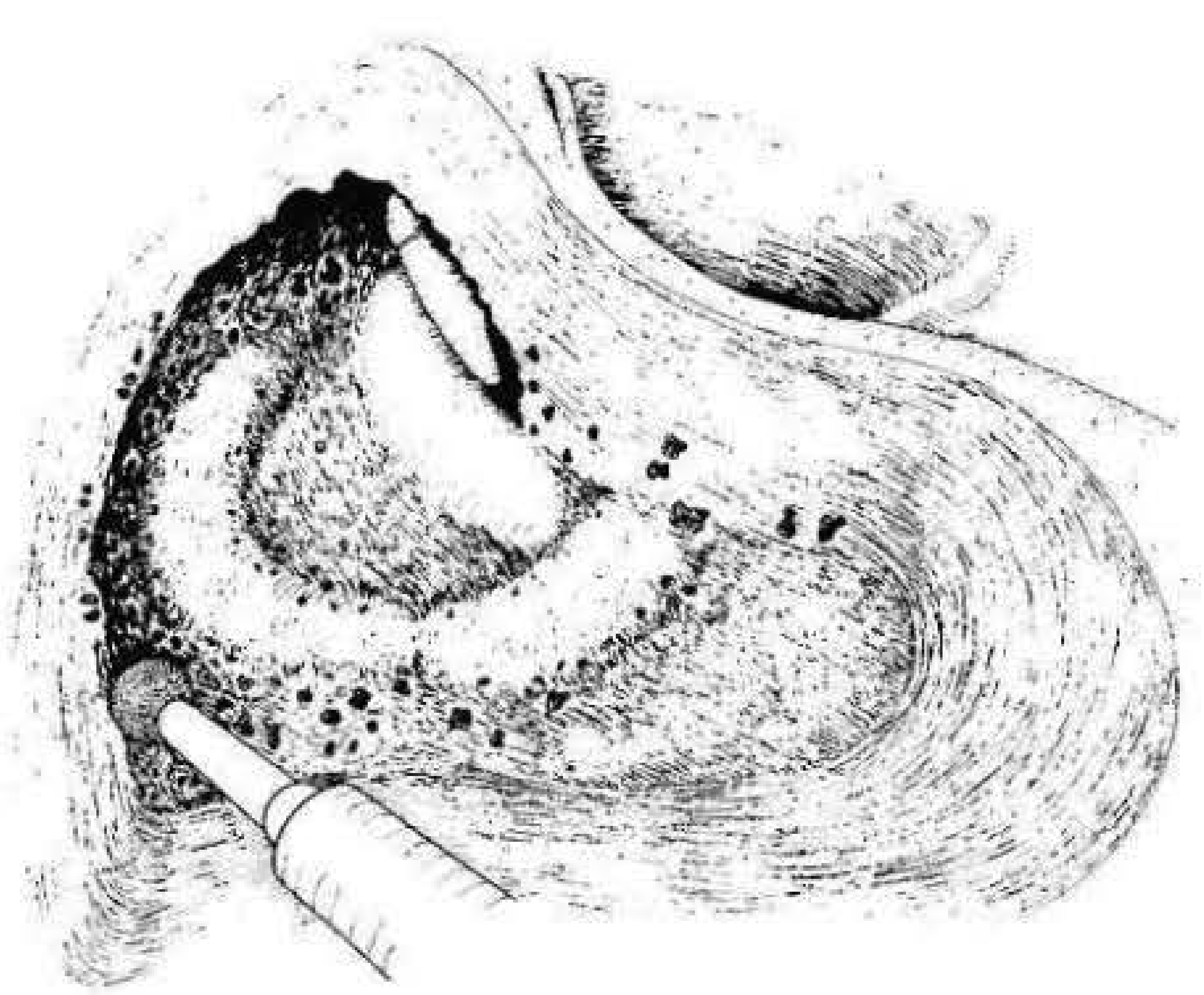


Fig. **216** **The superior perilabyrinthine cells** are exenterated using a small diamond burr, and the space between the contours of the superior semicircular canal and the middle fossa dura plate is carefully widened

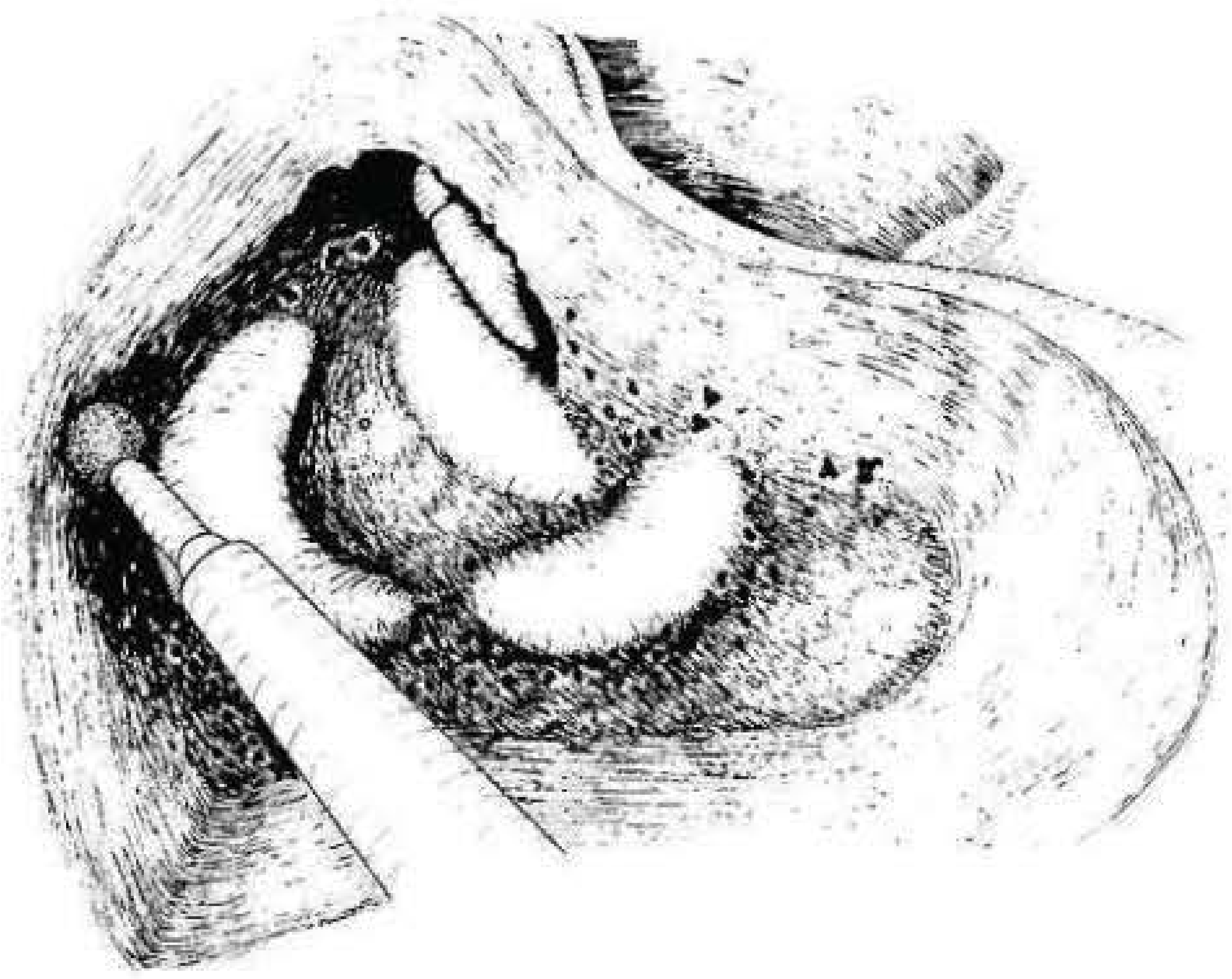


Fig. **217** The superior perilabyrinthine cells have been removed, and the entire superior semicircular canal clearly demarcated. Its walls are smoothed using a small diamond drill. The perilabyrinthine cells are exenterated, demarcating the walls of the posterior semicircular canal

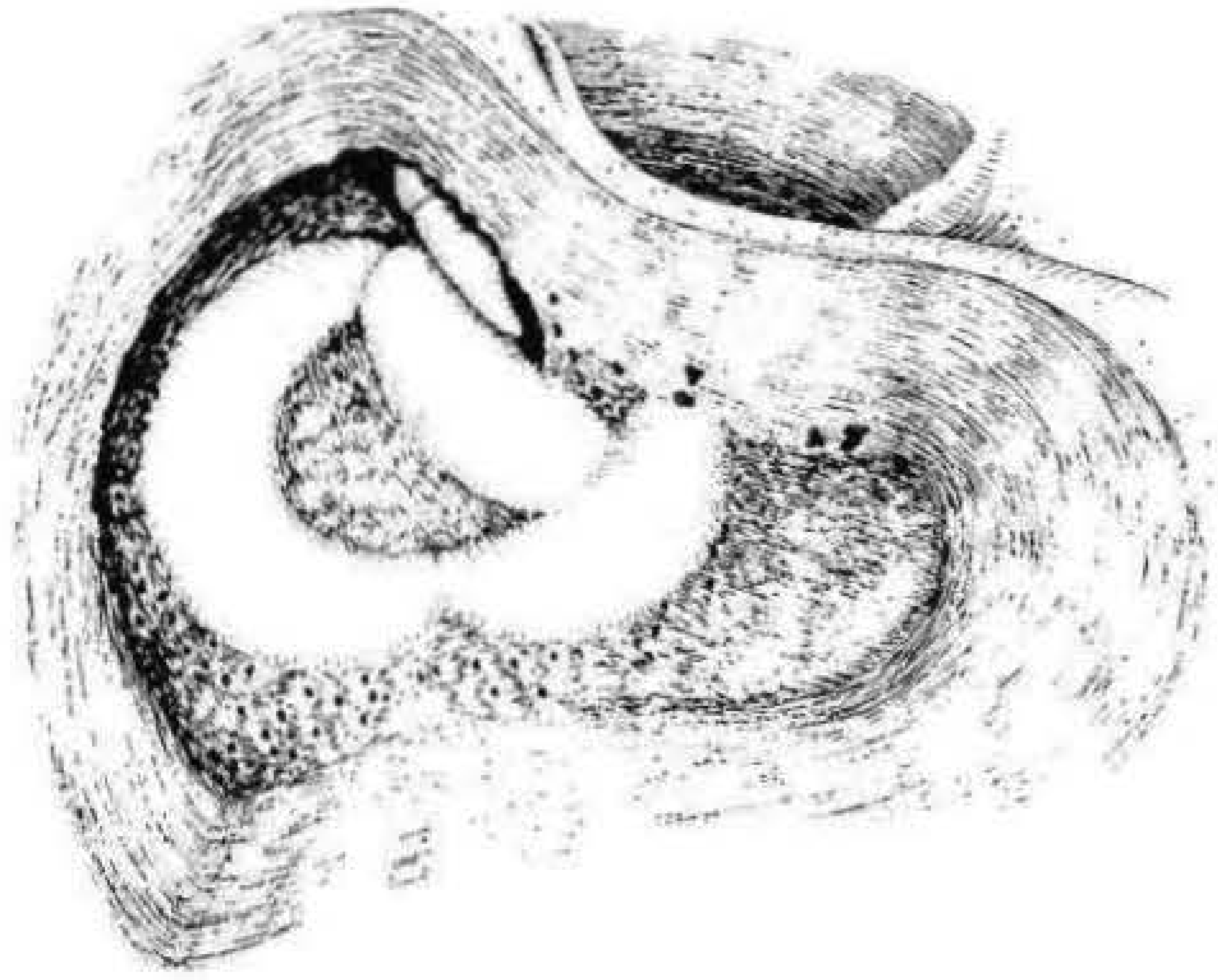


Fig. **218** All cells around the labyrinth have been exenterated, and the walls of all three semicircular canals have been cleaned and smoothed

Necessity of Exenterating of Perilabyrinthine Cells

When working around the labyrinth in a well-pneumatized ear with perilabyrinthine air cells continuing as tracts towards the pyramid, the question arises: when to stop?

In cases of *acute petrositis* associated with mastoiditis, once the simple mastoidectomy is completed, it may be that pus is seen to come out of the perilabyrinthine cells. This situation is extremely rare. In such cases, the perilabyrinthine cells have to be followed toward the petrous apex by gradual removal of the cell septa around the labyrinth using a curette.

In *noncholesteatomatous chronic otitis media* with severe infection and extensive pneumatization, the perilabyrinthine cells may be followed, the largest cells exenterated, and as much mucosa as possible removed, but the present author's opinion is that nothing is achieved by following the periantral cells in this manner.

In cases in which thin mucosa covers the perilabyrinthine cells, the cells should not be obliterated if canal wall–up mastoidectomy with re-pneumatization is to be performed. If canal wall–down mastoidectomy is to be performed, there is no need in the author's opinion to remove all the relatively nondiseased mucosa of the perilabyrinthine cells. It is sufficient to exenterate the larger cells and close the smaller cells by drilling with a diamond burr, creating a smoother perilabyrinthine space, but not necessarily a deeper one. The mucosa in such cells will become fibrotic and the cells will be obliterated. Larger cells may communicate with the tympanic cavity via the apical cells and via the cell tracts communicating with the apex and the Eustachian tube or hypotympanum. It is hard to see what benefit can be achieved from further exenteration of the deeper perilabyrinthine cells, creating a narrow space that has to be obliterated in any case in order to avoid a deep cavity. Drilling of the perilabyrinthine region is time-consuming and dangerous, and it requires exact knowledge of the anatomy and a good drilling technique to avoid trauma to the superior semicircular canal and resultant severe sensorineural hearing loss. The facial nerve is also at risk when drilling the superior perilabyrinthine cells.

Cholesteatoma Removal from the Perilabyrinthine Space

In cases of *cholesteatoma* extending into the perilabyrinthine space or even deeper, it is clear that the perilabyrinthine cells must be exenterated. In such circumstances, more extensive bone removal has to be performed in order to visualize the fundus of the cholesteatomatous extension. The bony plate of the middle fosa dura or posterior fossa dura, or both, is removed in such cases in order to improve visualization over the narrow perilabyrinthine space.

In *adult cholesteatoma,* the limited pneumatization or even sclerosis of the perilabyrinthine space restricts the cholesteatoma extending into the cells. The cholesteatoma is usually well-demarcated, and removing it is easier than it is in children. The technique for removal of the perilabyrinthine extension of cholesteatoma in adults with poorly pneumatized temporal bones is illustrated in Figures **182** and **186** to **188**. It is important to obtain good access to the perilabyrinthine space. Sometimes a prominent sigmoid sinus has to be exposed and retracted posteriorly (Fig. **182**) before further bone removal. A deep cholesteatoma can be elevated from the perilabyrinthine space by removing the middle and posterior fossa dura bony plates and displacing the dura posteriorly (Figs. **186–188**).

In *childhood cholesteatoma,* there is no sclerosis in the perilabyrinthine space when the cholesteatoma develops, and the periantral and perilabyrinthine cells are present. During cholesteatoma growth from the attic into the aditus and antrum, the cholesteatoma can easily extend into the perilabyrinthine cells as fingerlike protrusions, and these are a common finding in surgery. The cause of such extensions may be resorption of the air within the cell, followed by suction of the cholesteatoma matrix into the cells (Fig. **219**). During growth of the fingerlike cholesteatoma protrusions, they may extend into all perilabyrinthine cells (Figs. **220, 221**), and the cell septa may initially remain intact.

In children, dissection of cholesteatoma from the perilabyrinthine region must be performed in a special way by carefully evacuating each cholesteatoma protrusion from the individual cell before exenteration of the cell, using either a burr or a curette. Using a burr before total instrumental removal of the cholesteatoma can easily block the cell and wrap residual cholesteatoma inside a perilabyrinthine cell (Fig. **222**). The residual cholesteatoma may easily and silently grow deeper, following the perilabyrinthine cell tracts (Fig. **223**). Because of the pressure of the cholesteatoma, the cell septa are resorbed, and the *inclusion cholesteatoma* slowly grows within the perilabyrinthine space and manifests itself after as much as 10–15 years as a supralabyrinthine cholesteatoma, with a slight facial palsy indicating involvement of the geniculate ganglion region and the Fallopian canal. Later dizziness may be a sign of the labyrinthine fistula of the superior semicircular canal (Fig. **224**).

To avoid residual cholesteatoma and inclusion cholesteatoma in children, the present author therefore opens the cholesteatoma sac, removing most of the cholesteatoma mass (Fig. **225**) and carefully dissecting the matrix out of every single cell, using fine sucker tubes with strong suction and small elevators (Fig. **226**). After clearing the first cells of cholesteatoma and further elevating the cholesteatoma matrix, the cells already cleared of cholesteatoma can be exenterated by removing the cell septa with a curette (Fig. **227**). Further cells are managed in the same way: initial removal of the cholesteatoma, inspection of the empty cells, and exenteration of the cell walls. Dissection of the cholesteatoma continues from the lateral semicircular canal towards the translabyrinthine cells and via the translabyrinthine cells to the superior perilabyrinthine cells. Every translabyrinthine cell containing cholesteatoma is opened and the matrix elevated and suctioned out of the cell (Fig. **228**). After the cholestea-

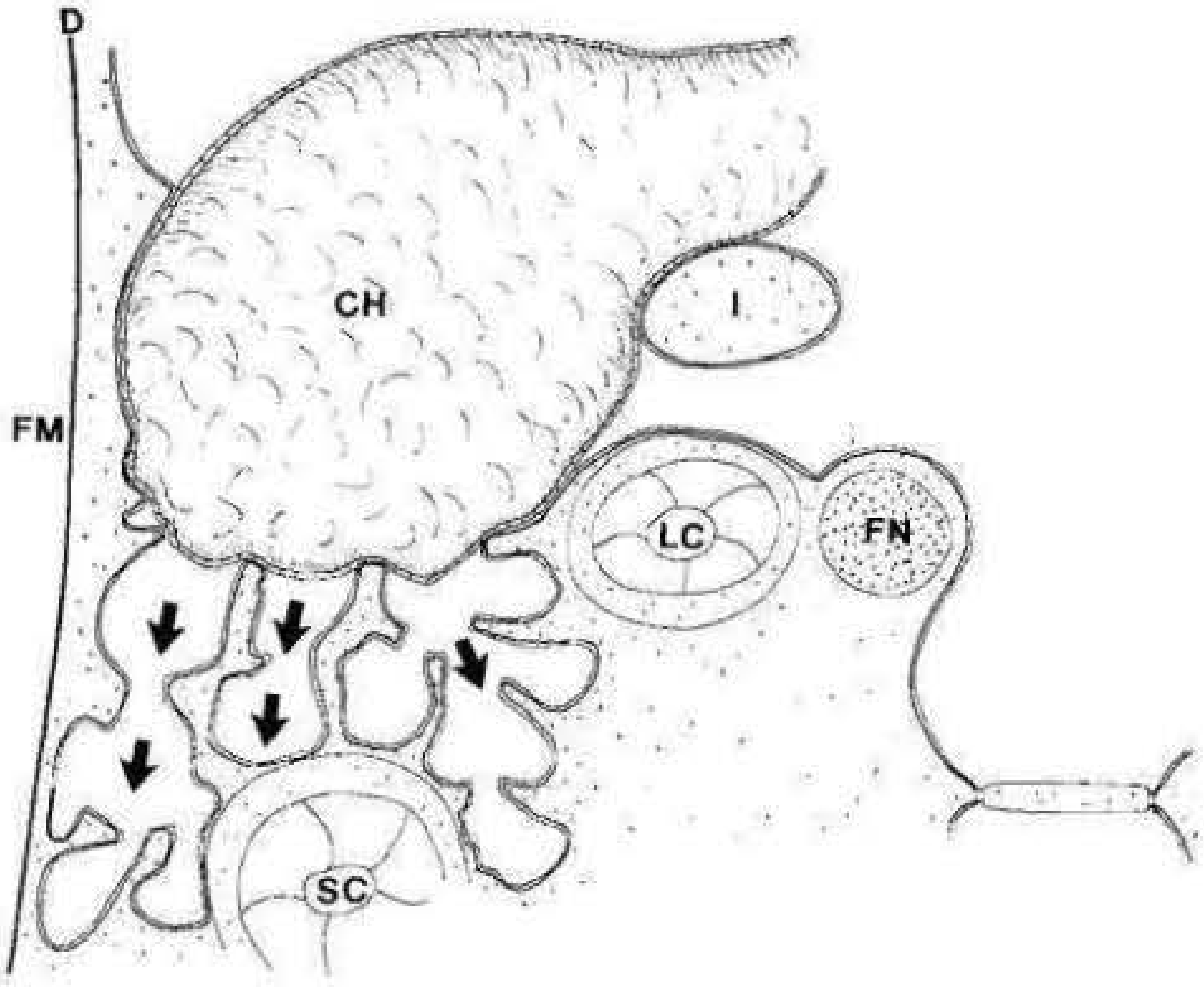


Fig. **219** **Growth of cholesteatoma into the perilabyrinthine air cells in a child.** The cholesteatoma is blocking the cells, and may be pulled into them by negative pressure. FM: fossa media; D: dura; CH: cholesteatoma; I: incus body; SC: superior semicircular canal; LC: lateral semicircular canal; FN: facial nerve

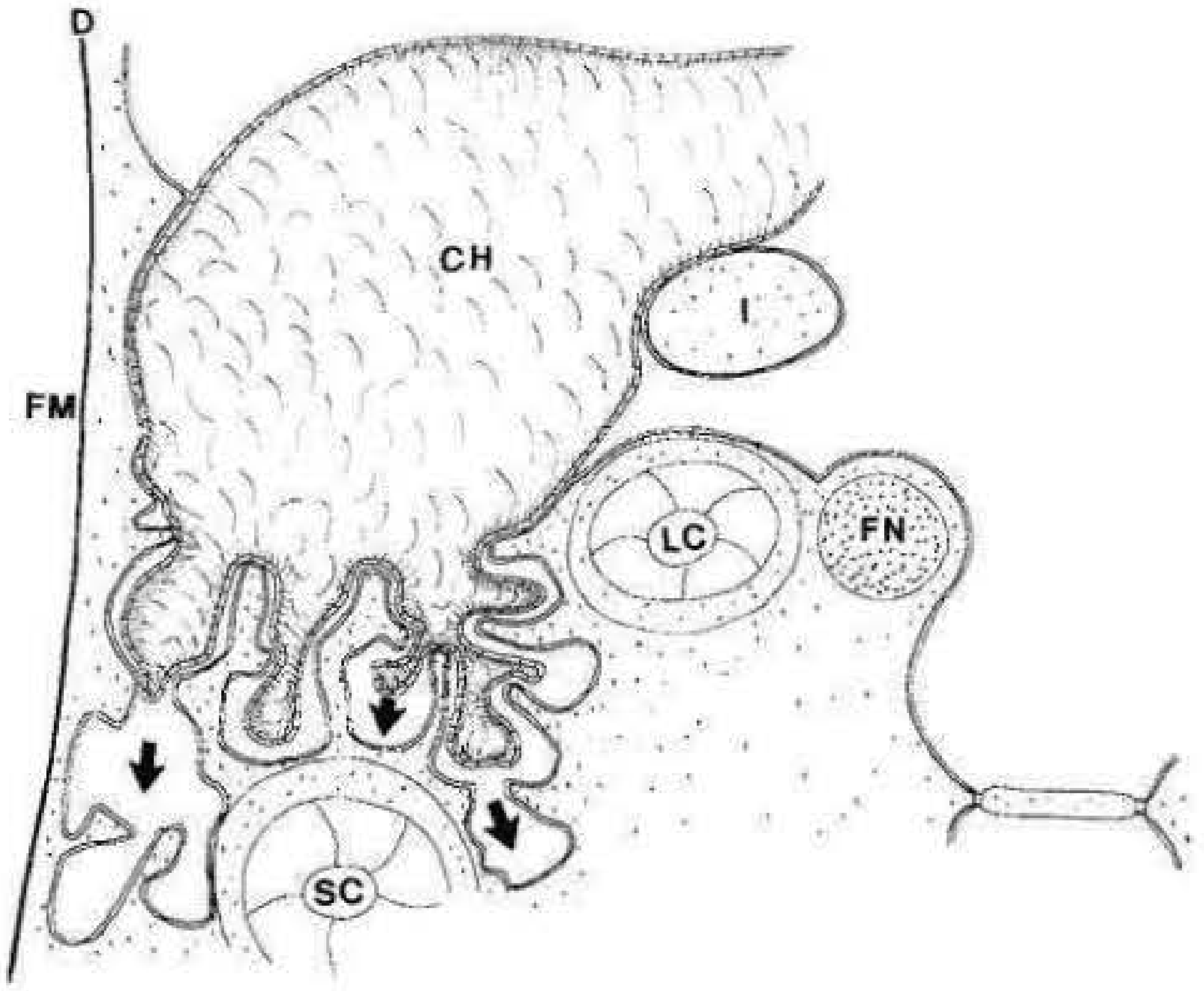


Fig. **220** Extension of the cholesteatoma into the superior perilabyrinthine and translabyrinthine air cells, with fingerlike protrusions (abbreviations as in Fig. **219**)

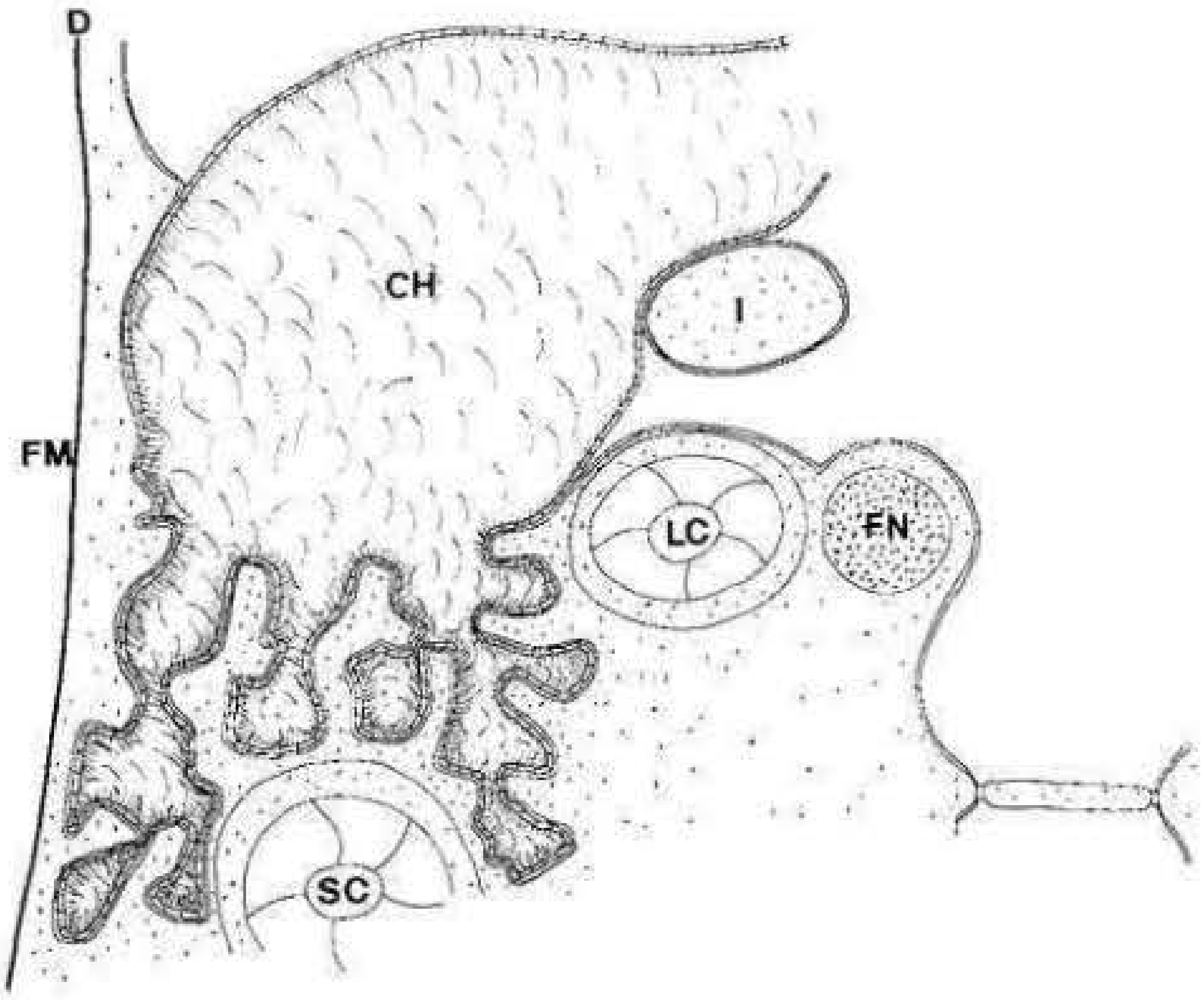


Fig. **221** Further growth of the cholesteatoma as fingerlike protrusions into all the perilabyrinthine and translabyrinthine air cells (abbreviations as in Fig. **219**)

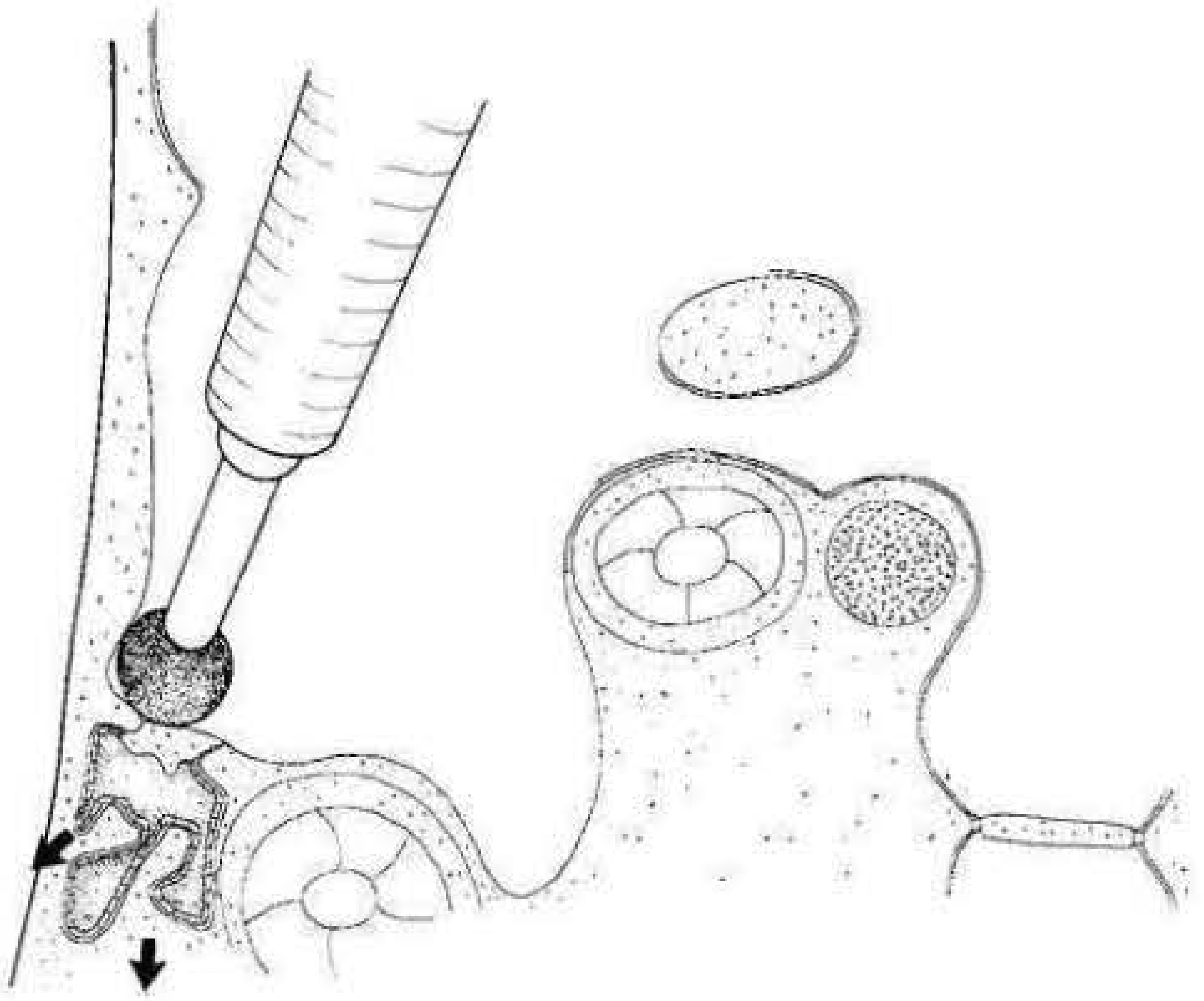


Fig. **222** **Incorrect and too early drilling of the perilabyrinthine space** before total removal of the cholesteatoma. The air cells are closed by the drilling, and the cholesteatoma is enclosed within the supralabyrinthine space, where it will continue to grow along the perilabyrinthine cell tracts

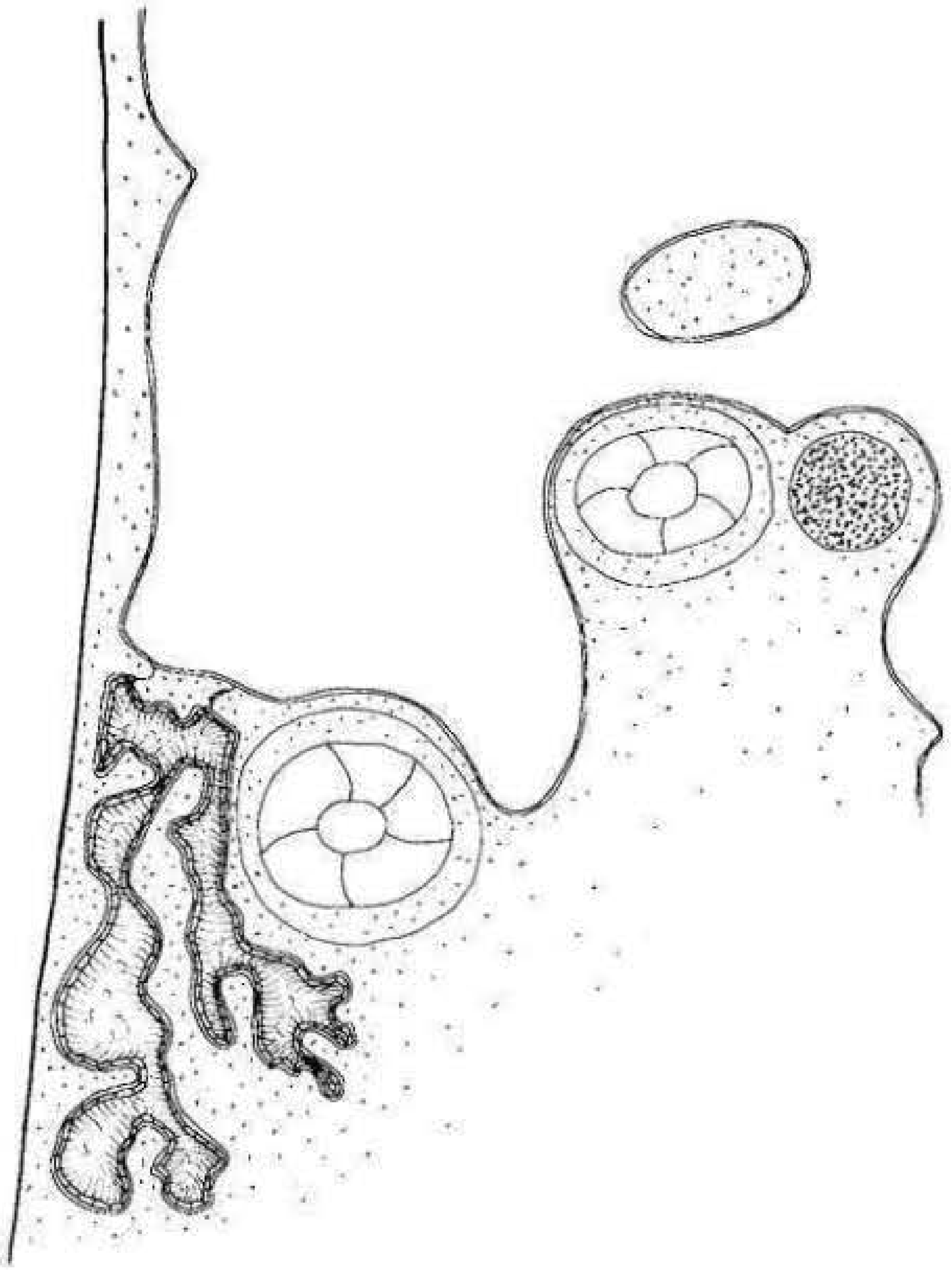


Fig. **223** Further growth of the cholesteatoma along the superior perilabyrinthine cells

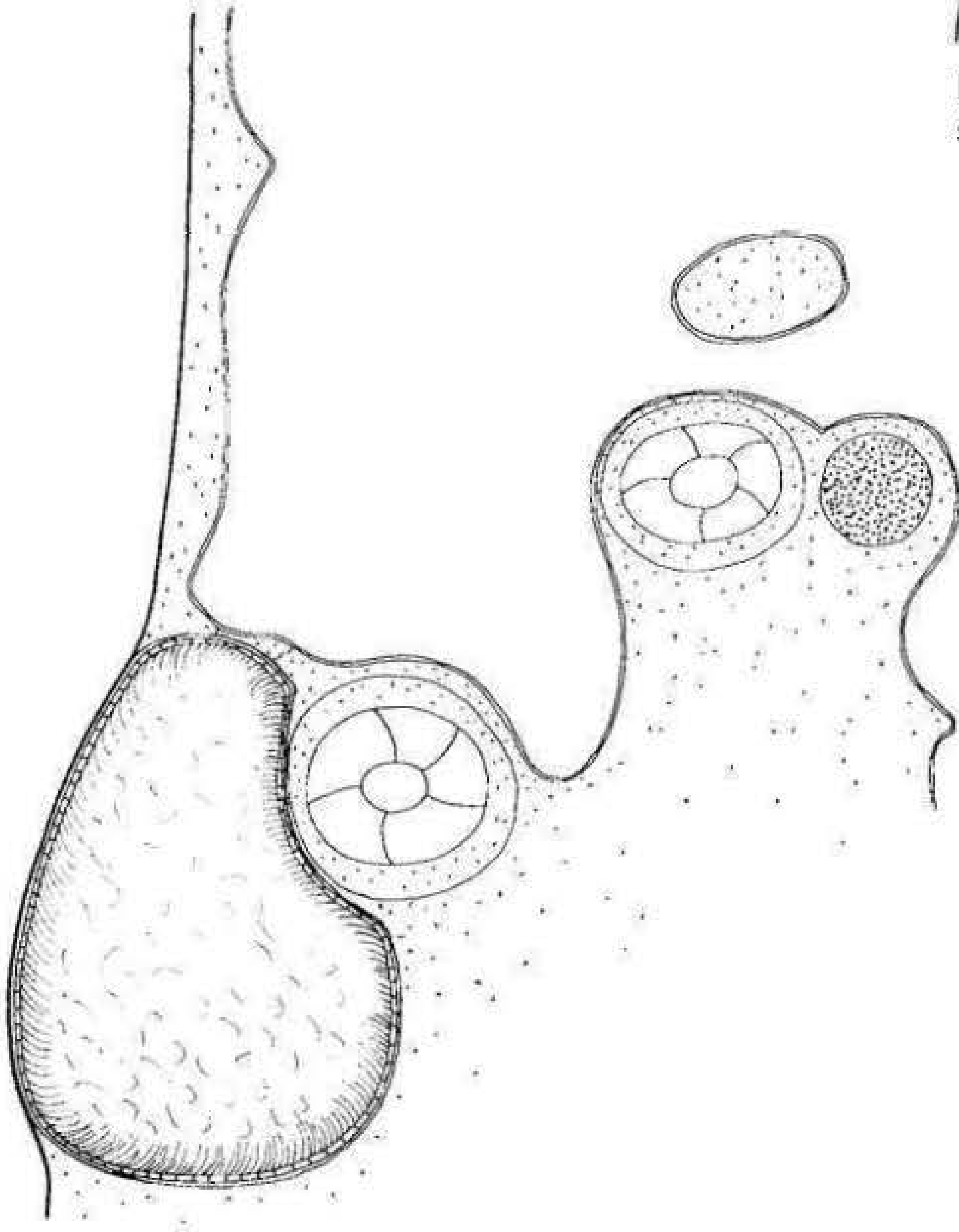


Fig. **224** The bony septa of the cells can gradually be resorbed. The supralabyrinthine inclusion cholesteatoma is growing expansively, and incipient erosion of the bony wall of the superior semicircular canal is taking place

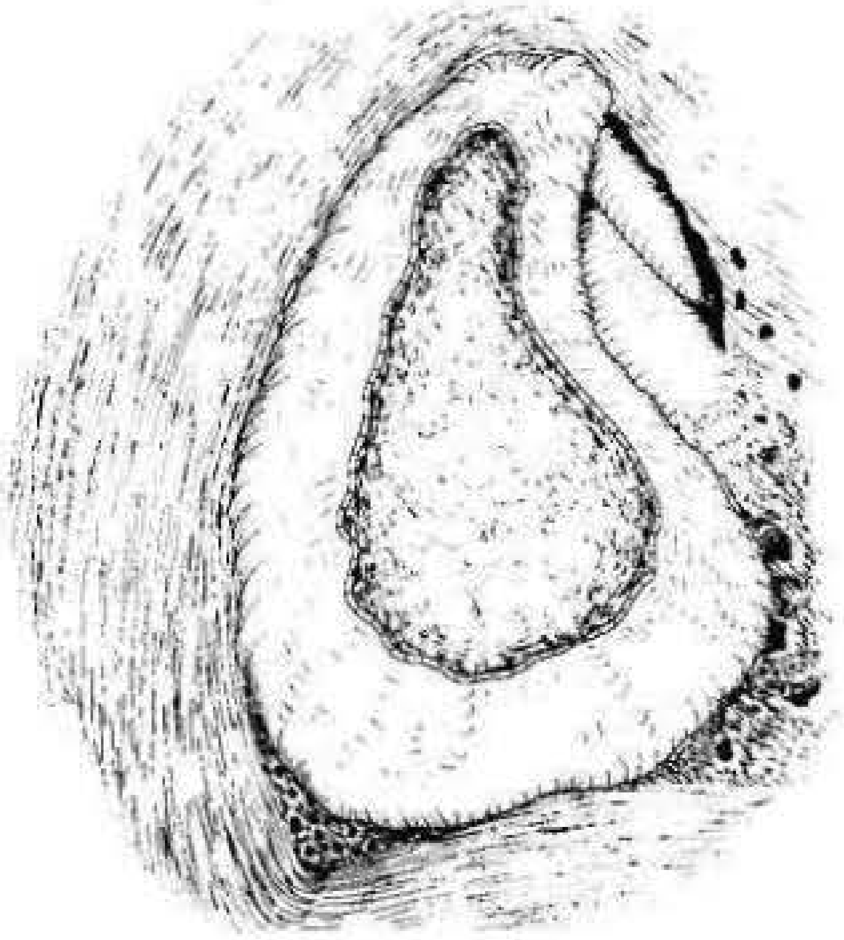


Fig. **225** **Management of cholesteatoma in children as practiced by the present author.** The cholesteatoma sac is opened and the mass is removed

Fig. **226** The matrix is carefully elevated, and a search is made for fingerlike protrusions into the air cells. The protrusion is elevated with a small elevator or a sickle knife and a suction tube

Fig. **227** Further elevation of the matrix and removal of the cholesteatoma. The perilabyrinthine cells, cleaned of cholesteatoma, are exenterated with a curette

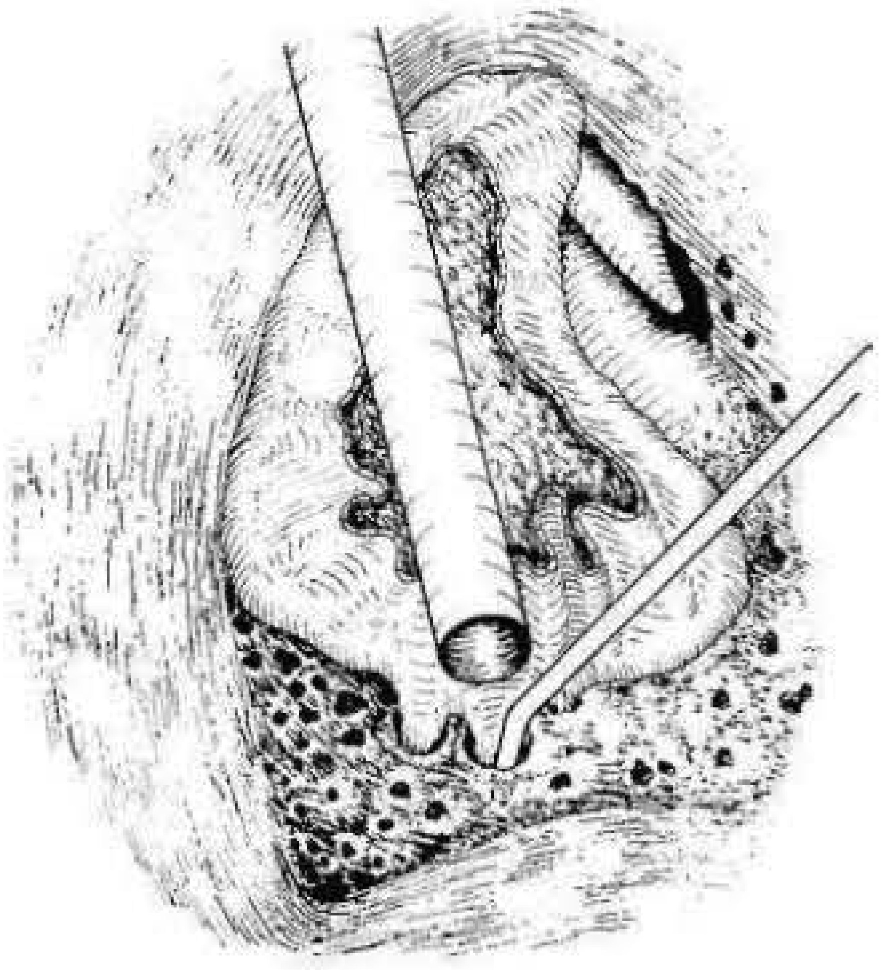


Fig. **226**

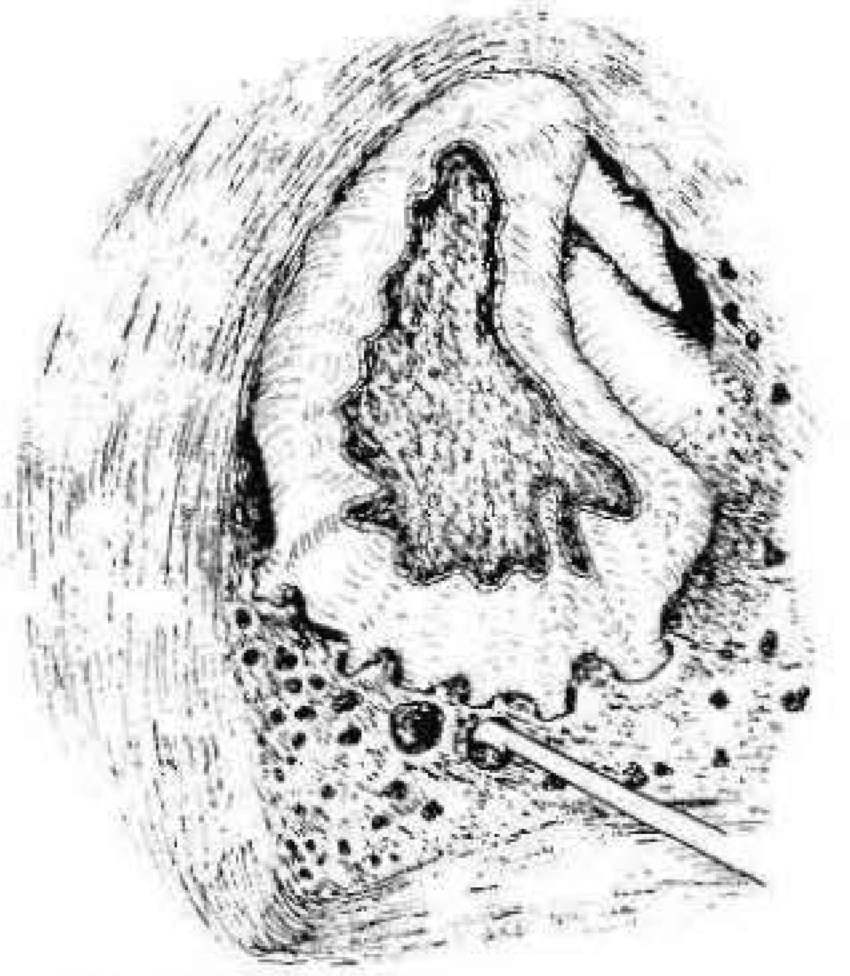


Fig. **227**

toma has been removed, the cell septa can be removed and the cell wall polished using a small diamond burr (Fig. **229**). With continued cell-by-cell removal of the cholesteatoma from all the translabyrinthine cells (Fig. **230**), the superior perilabyrinthine cells are cleared along the superior semicircular canal (Fig. **231**). The cholesteatoma matrix is elevated from the deepest perilabyrinthine cells (Fig. **232**), and the matrix is removed by "inward-to-outward" elevation out of the perilabyrinthine space (Fig. **233**). The cell septa are broken down using a curette (Fig. **234**), enlarging the space and carefully inspecting for any remnants of the cholesteatoma matrix in the bottom of the cells or continuation of the cholesteatoma into a more deeply situated air cell. After complete removal of the cholesteatoma (Fig. **235**), polishing of the perilabyrinthine space with a diamond burr is performed (Fig. **236**).

The third way of removing cholesteatoma protrusions within the perilabyrinthine air cells is by dissection along the middle fossa dura plate and careful elevation of the matrix (Fig. **237**), after removal of the middle fossa dura plate (Fig. **238**) to improve access and then removal of the entire cholesteatoma membrane (Fig. **239**).

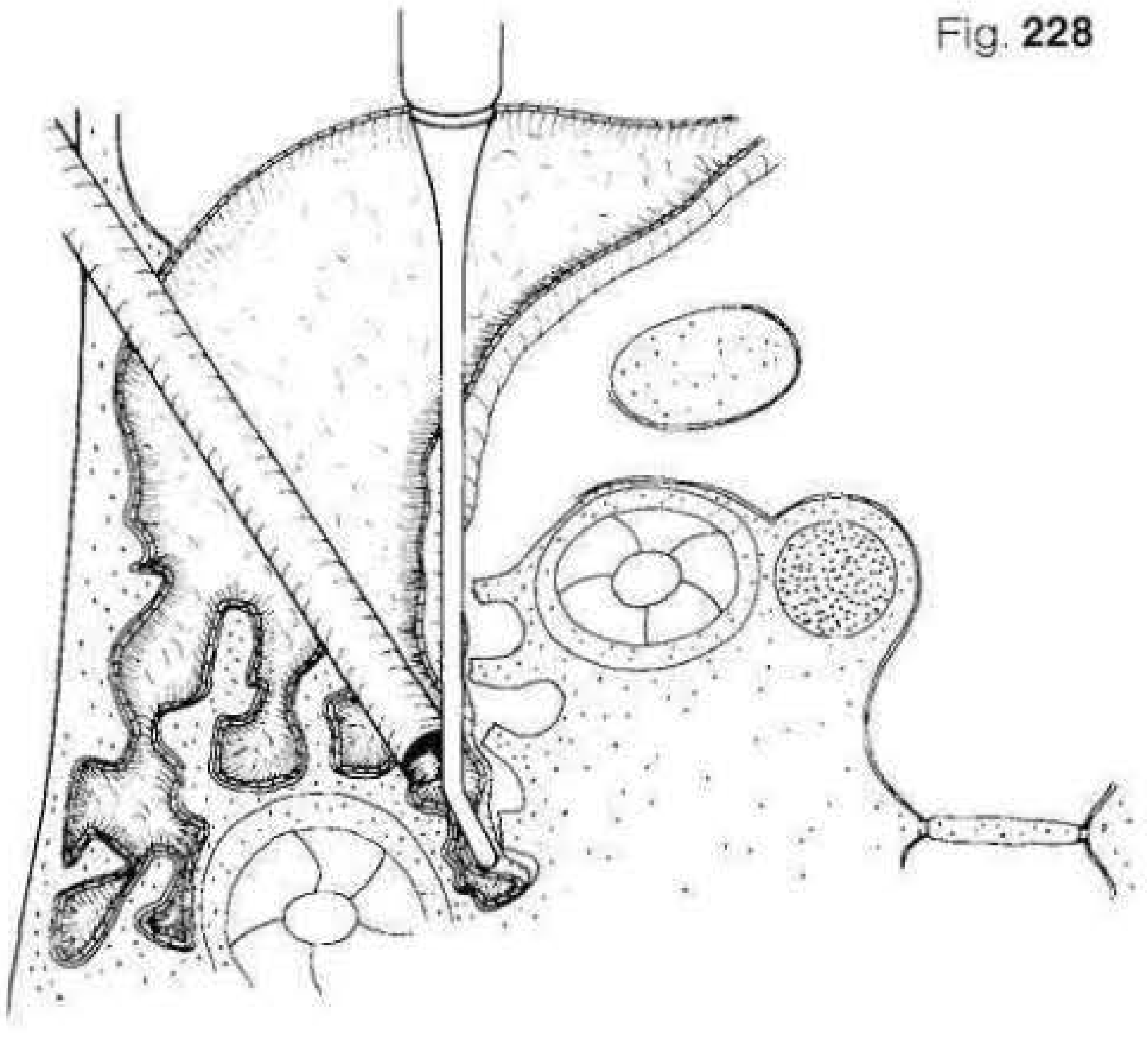


Fig. **228**

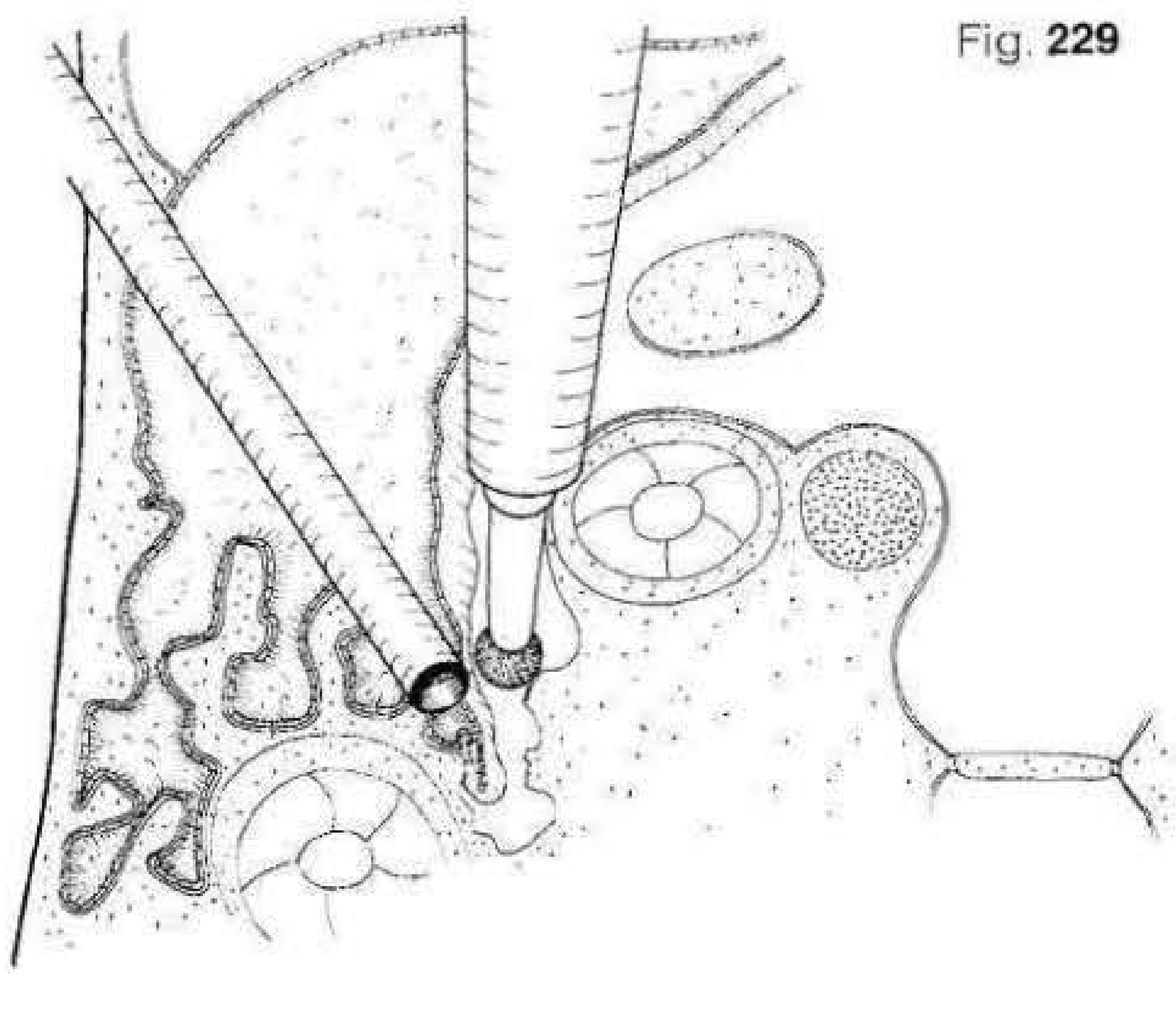


Fig. **229**

Fig. **228** Removal of the cholesteatoma from the translabyrinthine cells. Each cell is cleaned separately by elevating the matrix from the cell

Fig. **229** After cleaning the cells, the cell septa are removed, and the walls are smoothed with a diamond drill

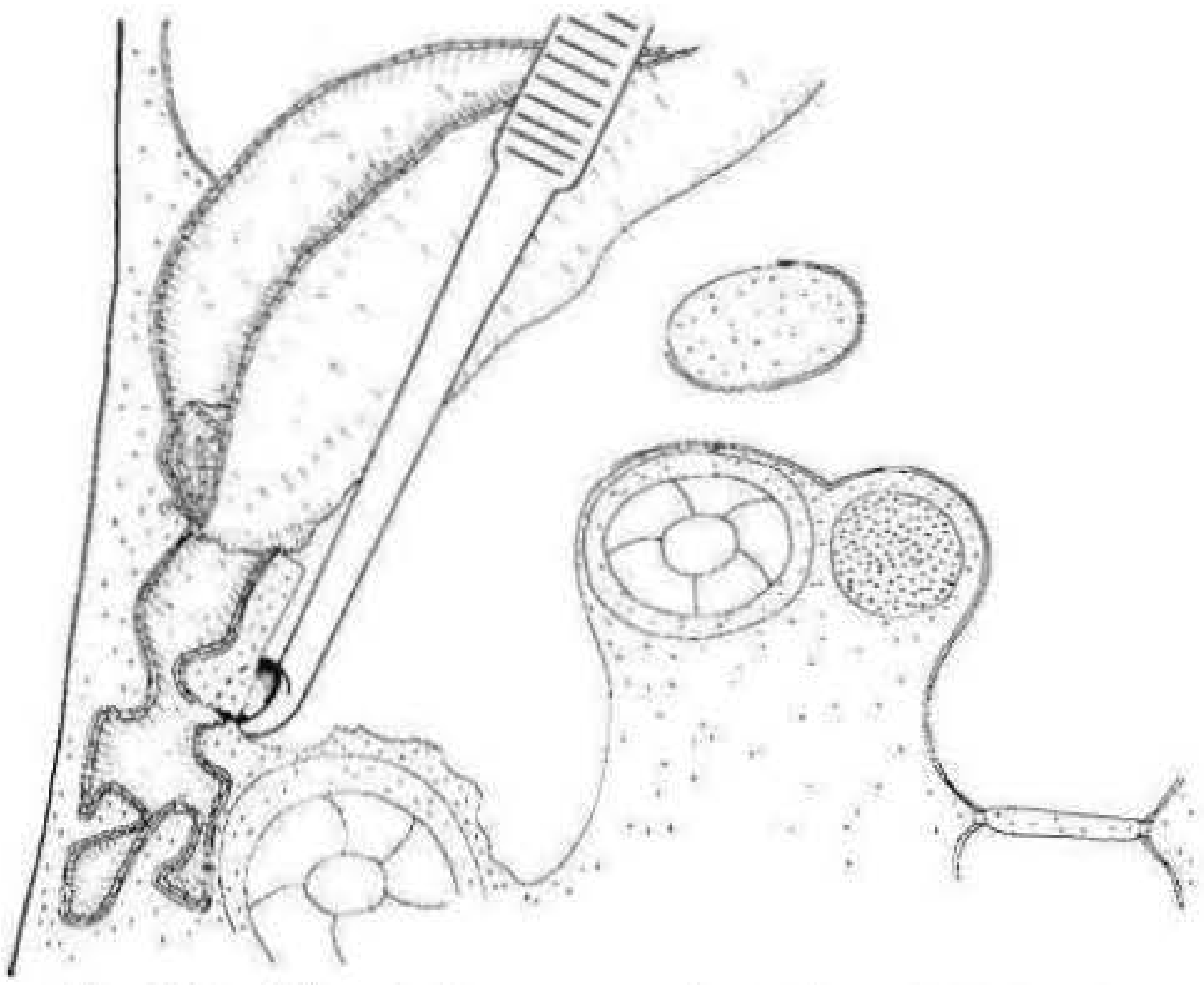


Fig. **230** After further removal of the cholesteatoma from the translabyrinthine cells, the cell septa are removed with a curette, and the superior perilabyrinthine region is entered

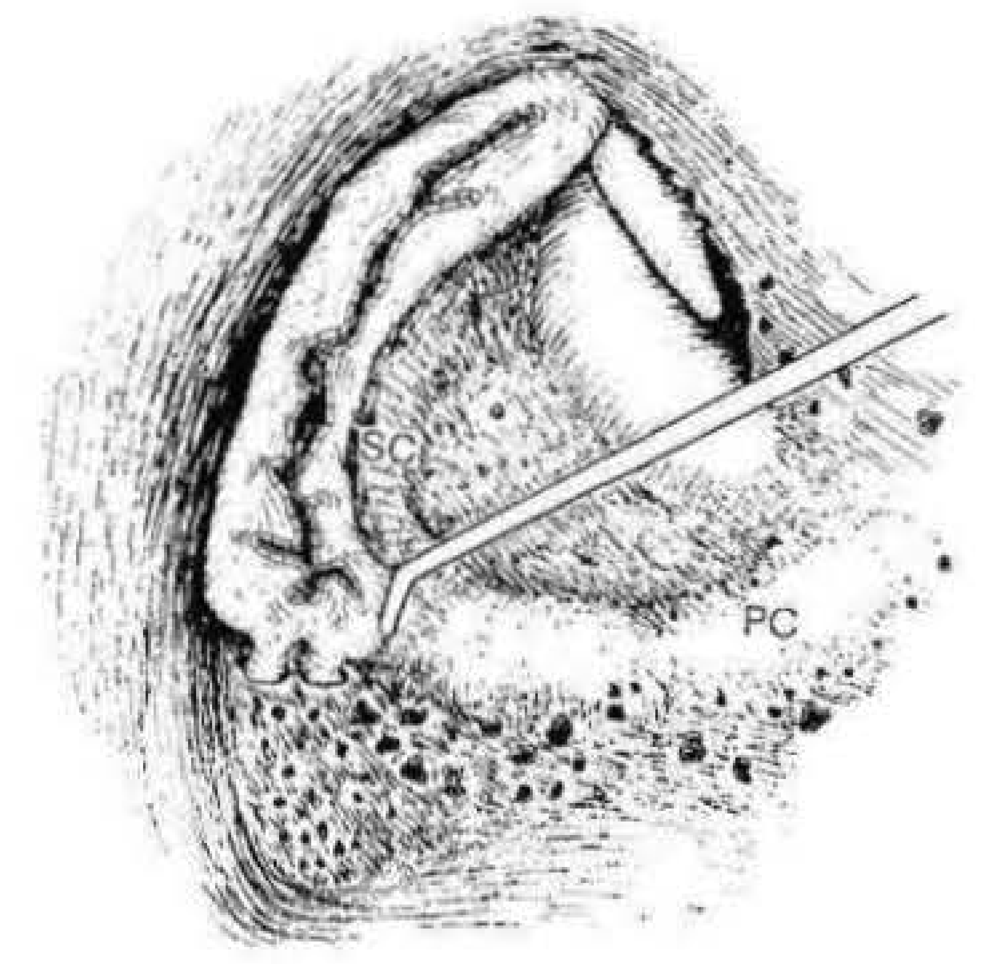


Fig. **231** The fingerlike protrusions into the perilabyrinthine cells are removed from the posterior and anterior aspect after the cholesteatoma has been removed from the translabyrinthine area, which has been smoothed. The contours of the superior semicircular canal (SC) and the posterior semicircular canal (PC) are visible

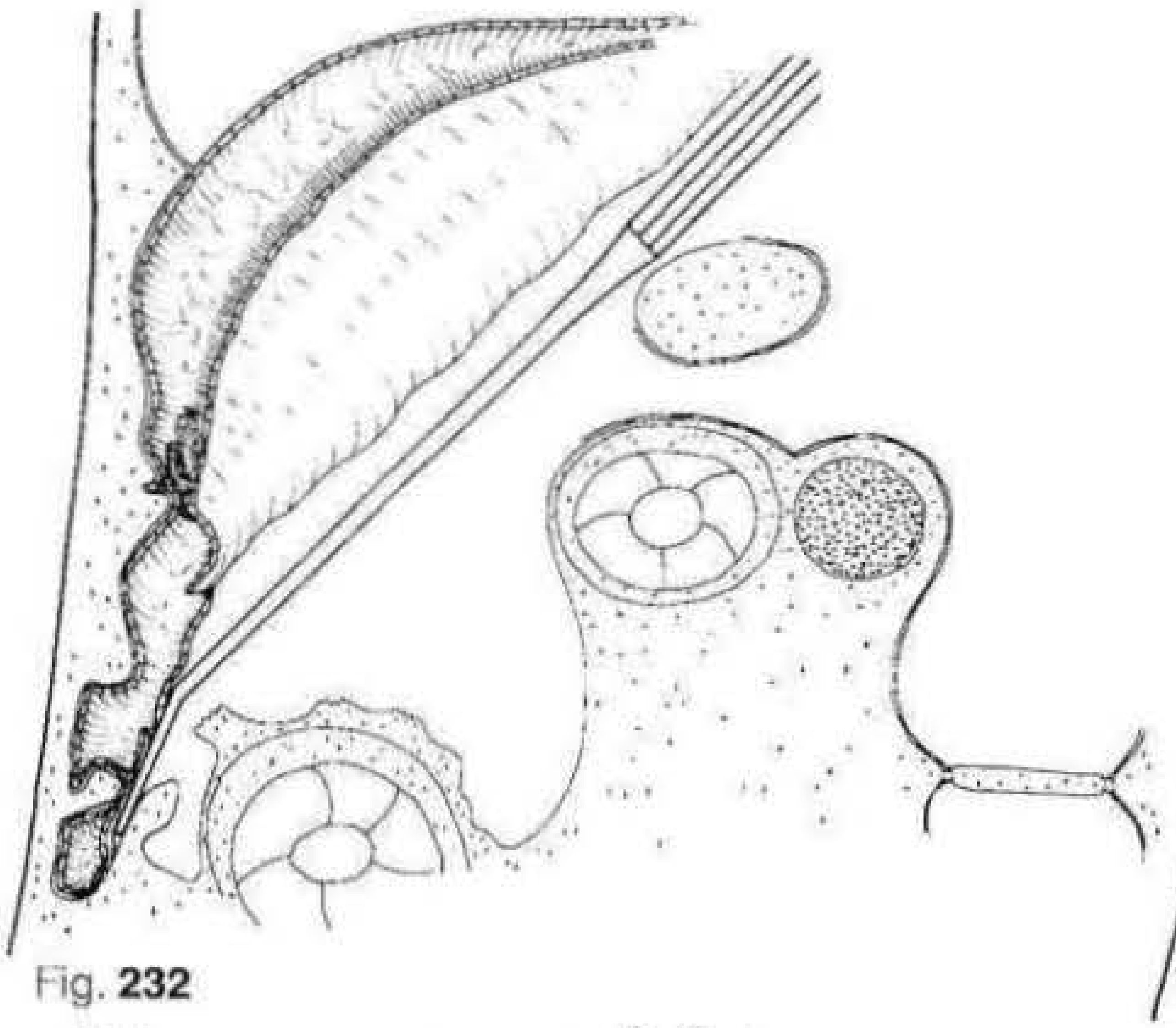


Fig. **232**

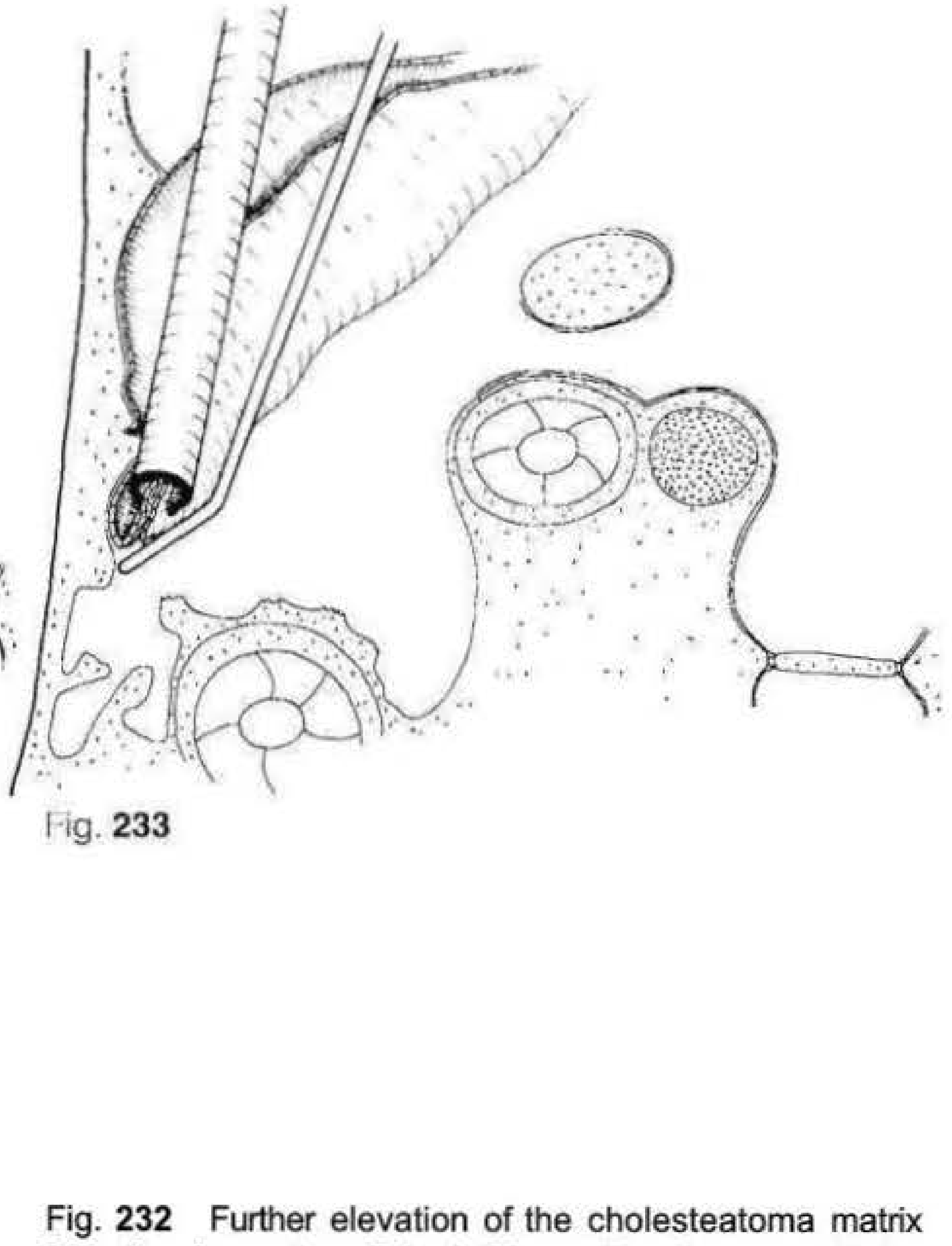


Fig. **233**

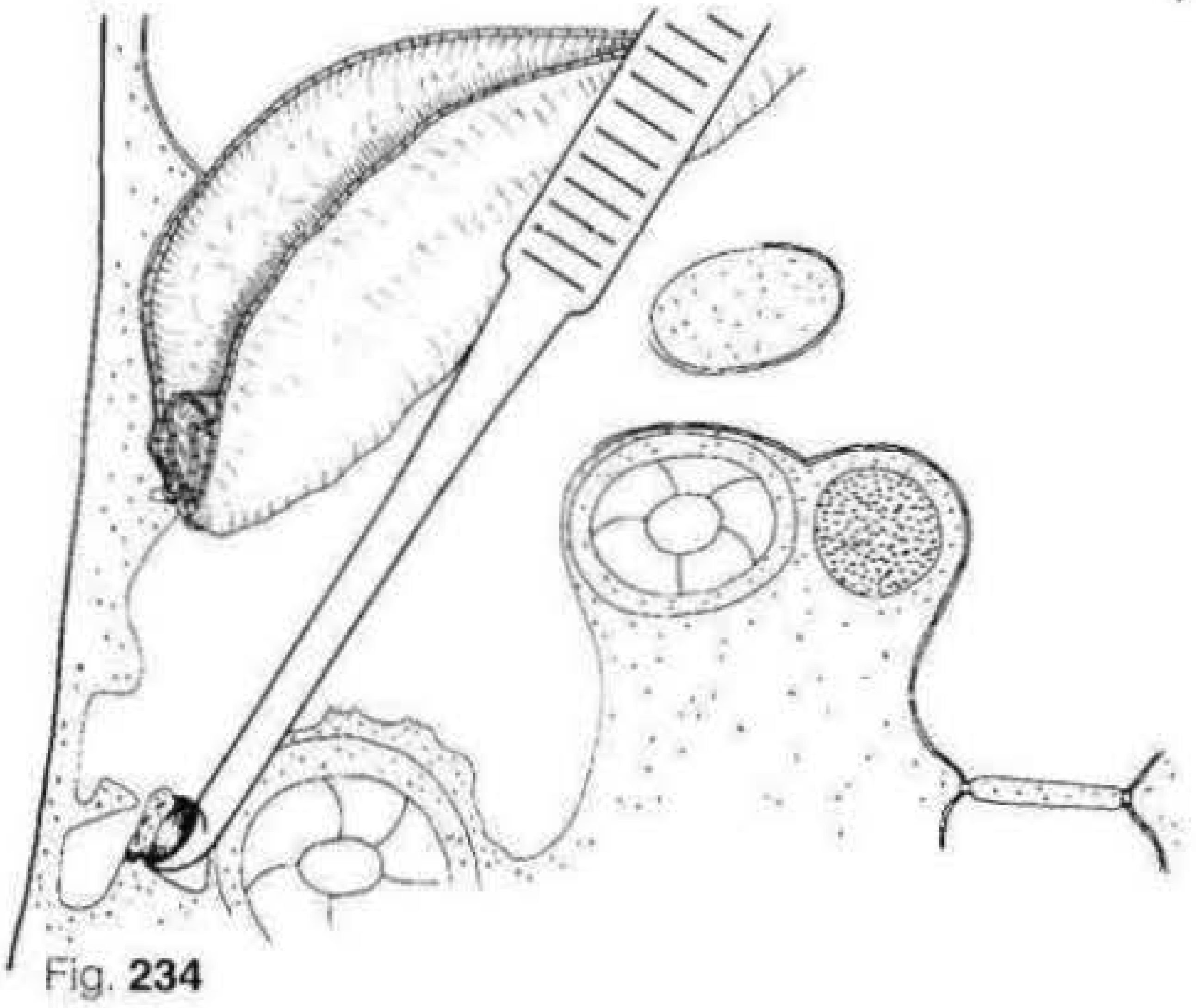


Fig. **234**

Fig. **232** Further elevation of the cholesteatoma matrix from the deepest perilabyrinthine cells using a small elevator

Fig. **233** The matrix has now been totally elevated out of the perilabyrinthine space

Fig. **234** The cell septa are removed with a curette

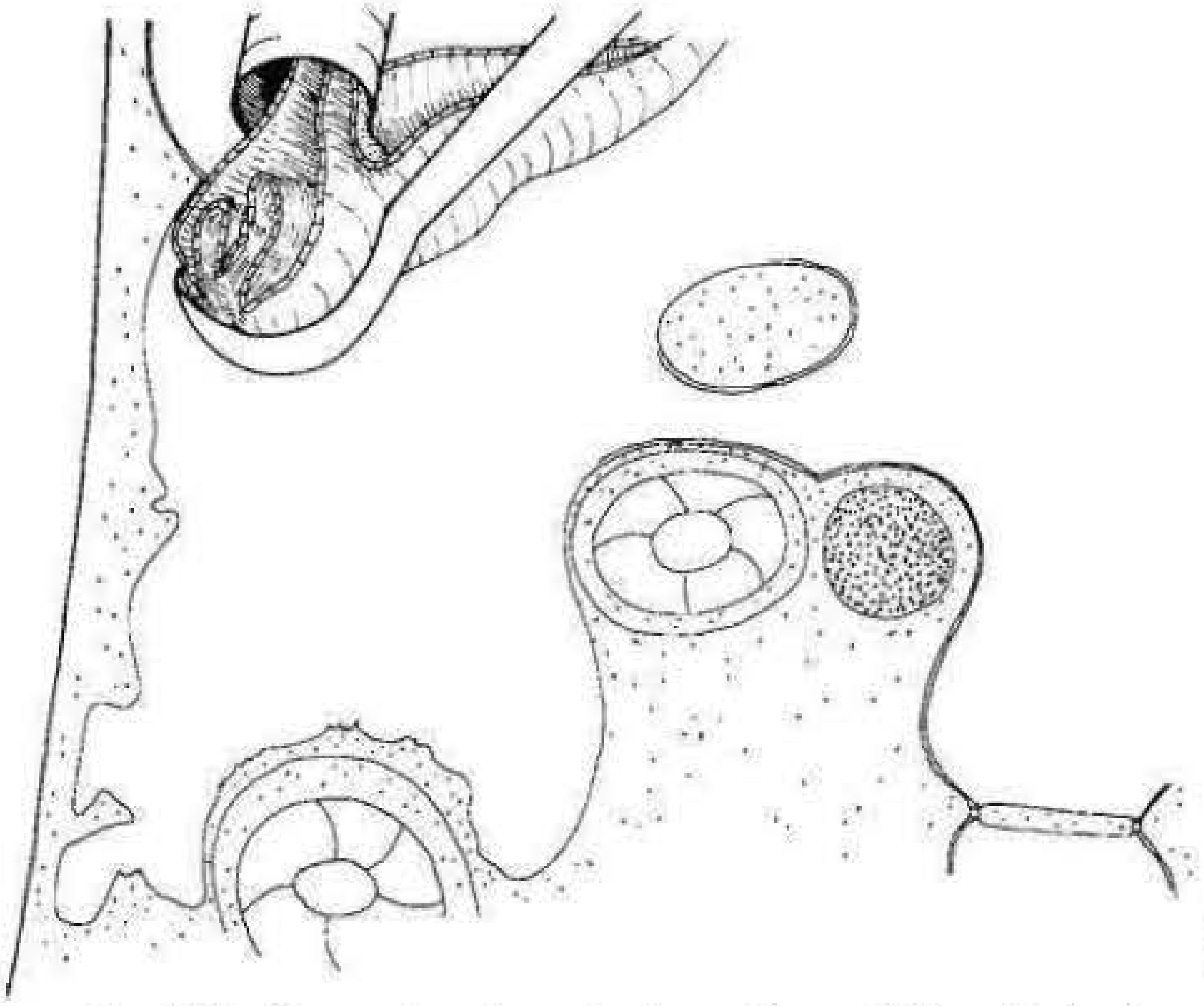


Fig. **235** Inward–outward dissection of the cholesteatoma matrix

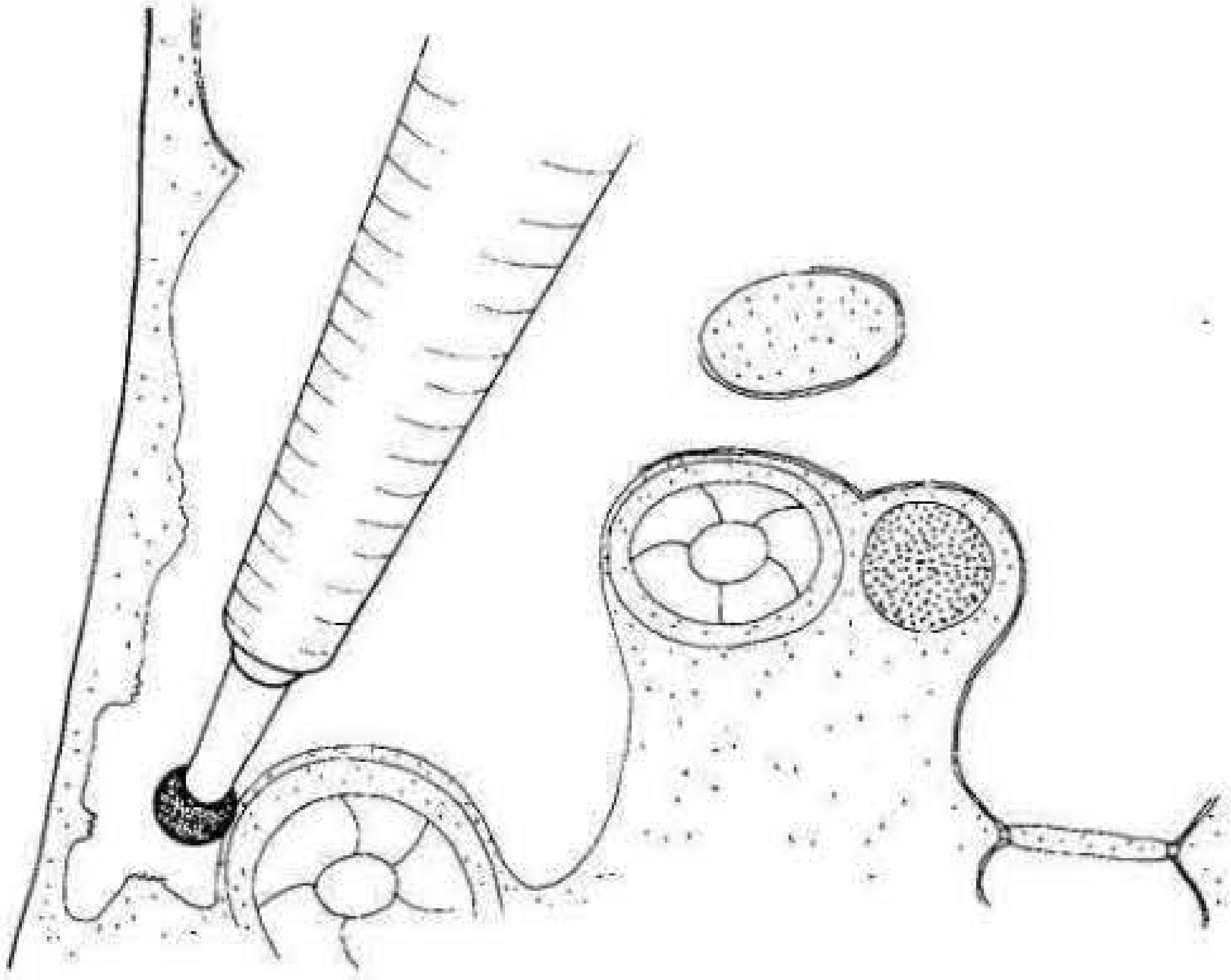


Fig. **236** The perilabyrinthine space is carefully inspected, and the sharp edges are smoothed with a diamond drill

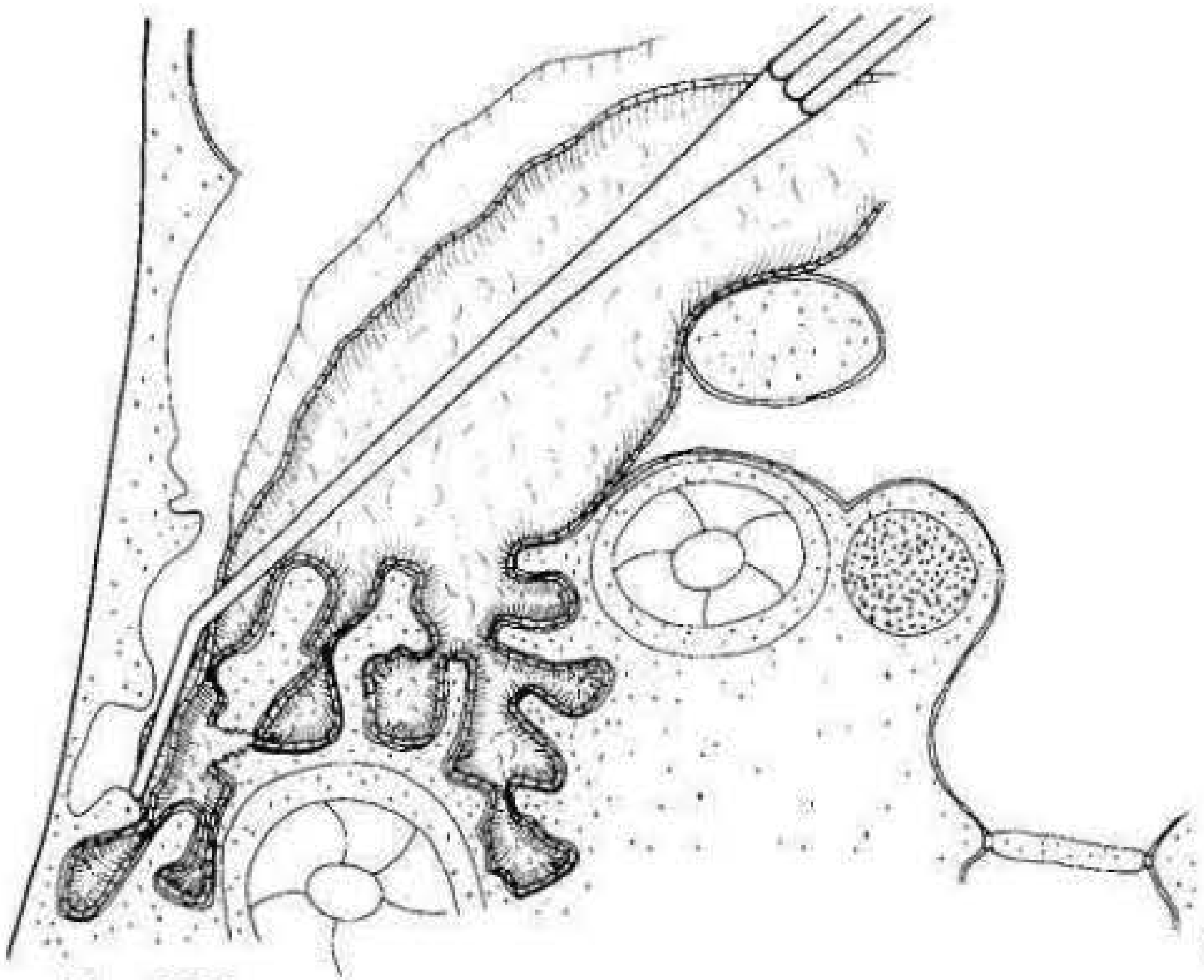


Fig. **237**

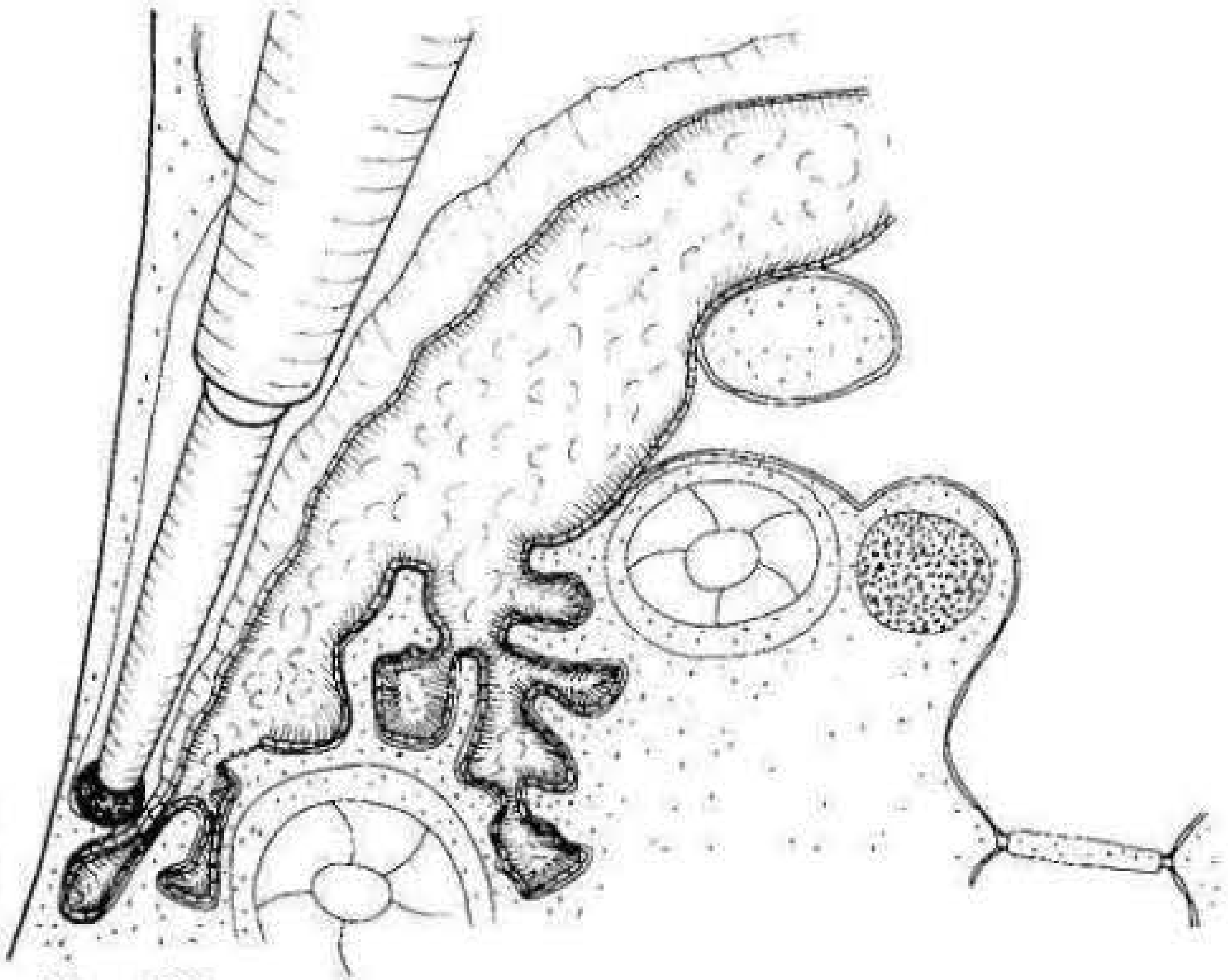


Fig. **238**

Fig. 237 **Elevation of the perilabyrinthine extension of cholesteatoma in children** along the middle fossa dura plate. Using an elevator, the matrix is carefully elevated along the dura

Fig. **238** The bone is removed close to the dura, enlarging the access to the perilabyrinthine space

Fig. **239** The cholesteatoma is removed from the perilabyrinthine space. Removal continues toward the translabyrinthine angle

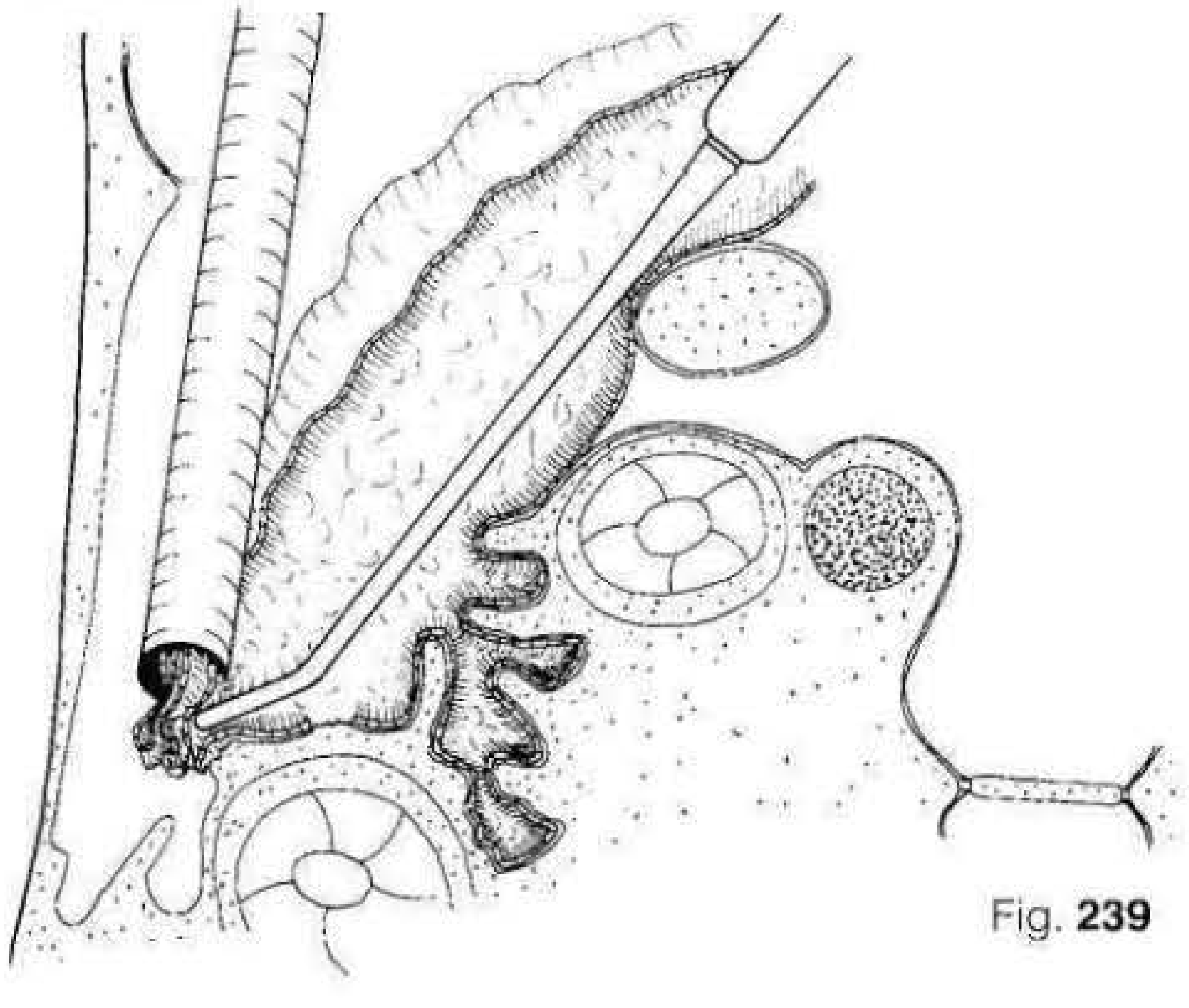


Fig. **239**

5 Simple (Cortical) Mastoidectomy

Definitions

The term *simple mastoidectomy* refers to the operation for acute coalescent mastoiditis. Originally, this operation consisted of removing the cortex from the lateral surface of the mastoid process, locating the antrum, wide opening of the abscess cavity, and removal of the surrounding softened air cells and granulations with a curette (Fig. **240**), while leaving the intact air cells in place. The wound was not closed primarily, but packed with a long strip of iodoform gauze (Fig. **241**) and left open. The packing was is changed every two or three days until the purulent discharge had ceased and the mastoid cavity had filled with healthy granulation tissue, usually three to five weeks after the operation. This operation was also described as an *antrotomy.*

Today, the cell exenteration is more complete, since all accessible cells from the squama, the mastoid process, and the periantral and perilabyrinthine areas are removed, including all coalescent foci of suppuration. The wound is always closed primarily. The operation has thus changed from being a simple mastoidectomy to a *complete mastoidectomy,* but the original name is still widely used for these operations.

Another discrepancy from the original terminology is the performance of a *cortical mastoidectomy* for various nonacute indications, such as subchronic and chronic aural discharge, as well as persistent discharge in chronic secretory otitis, treated with grommets, or recurrent acute purulent otitis media and other conditions. As mentioned in Chapter 1, cortical mastoidectomy is a preliminary part of many surgical procedures. To avoid confusion, the term *simple mastoidectomy* will be used only when performed in coalescent mastoiditis in infants, and the term *cortical mastoidectomy* will be used in all other indications requiring transcortical opening of the mastoid process and in all older children and adults.

History

The first recorded successful mastoidectomy to relieve aural discharge was performed by Jean Petit (1774). In 1776, Jasser, a Prussian military surgeon, successfully operated on a soldier's mastoid process.

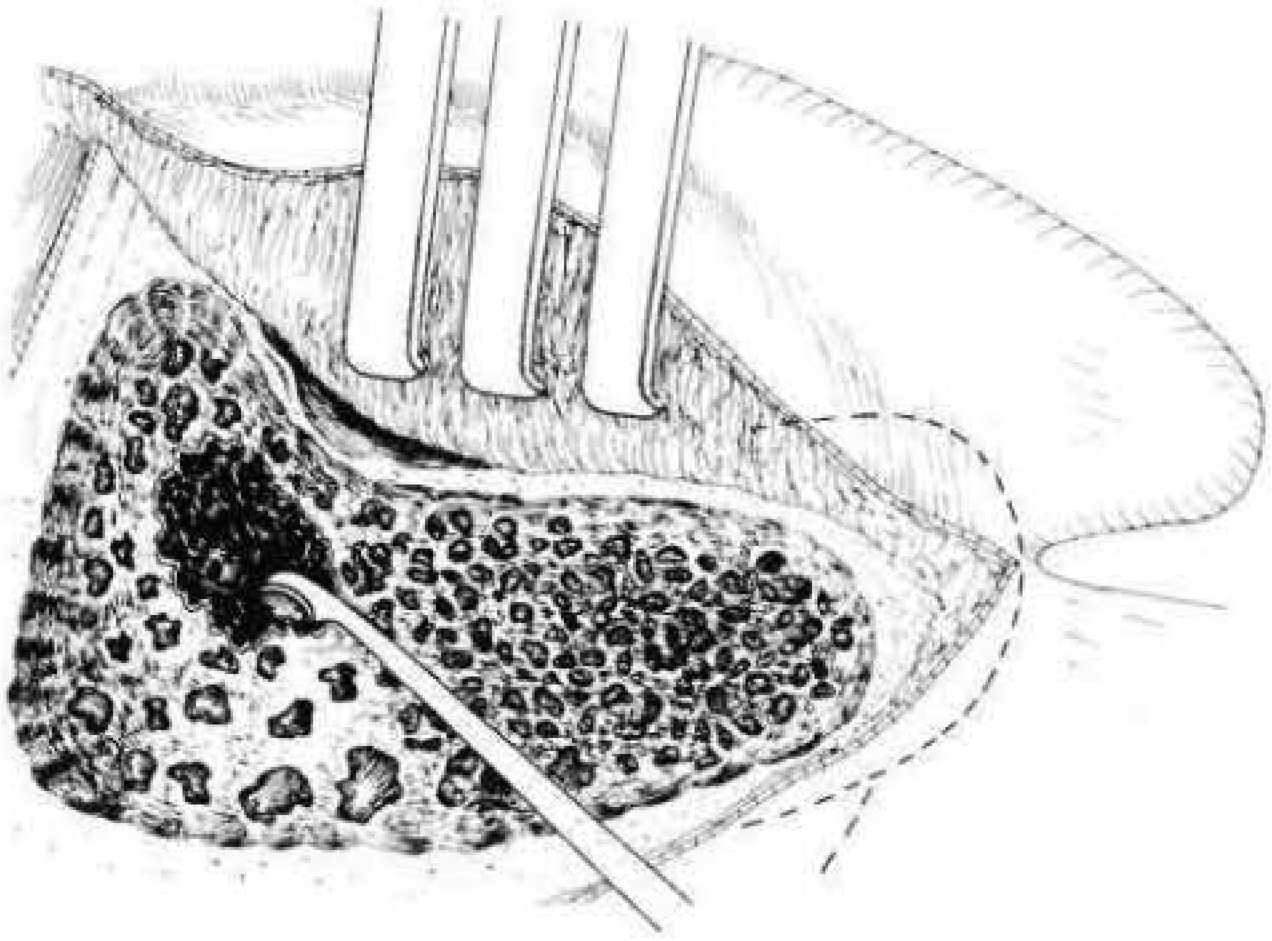


Fig. **240** **Antrotomy with drainage of the antrum as an open procedure:** The lateral mastoid cells are removed. The antrum is opened with a curette, and the granulation tissue is removed. Inferiorly in the mastoid process, the air cells are not developed

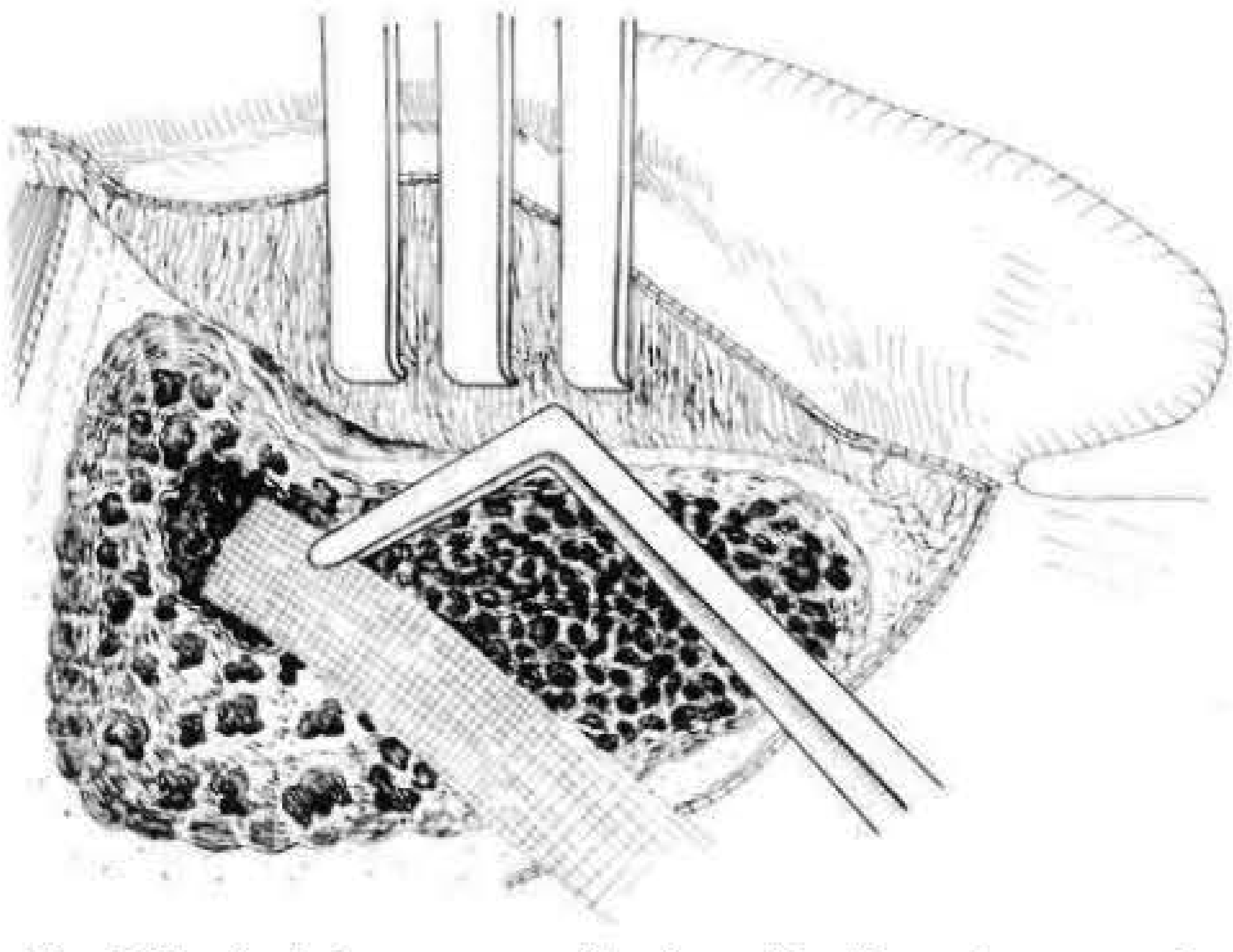


Fig. **241** Iodoform gauze ist placed in the antrum, and covers all the denuded bone. The gauze is changed every three days, and the cavity gradually becomes granulated from inside

Unfortunately, because the indication was wrong and the outcome unfortunate after a mastoidectomy performed on a person close to the Danish royal family, the operation fell out of favor for the following hundred years. The personal physician to the King of Denmark, Baron Bergen, suffering from deafness and tinnitus, asked his friend and colleague Kølping, who was the King's personal surgeon, to drill out his mastoid process in order to relieve him of tinnitus. The operation was, of course, undertaken without any surgical asepsis, and Bergen died 12 days later. In 1853, Sir William Wilde introduced the famous retroauricular incision for suppuration of the ear with retroauricular abscess, but he advised against opening the bone unless there were life-threatening symptoms, and apparently he never carried out a mastoidectomy. In 1873, Schwartze and Eysell described the indications for, and technique of, the mastoid operation, and by the end of the nineteenth century, the simple mastoidectomy was generally accepted. In 1905, Whiting stated that "as a life-saving measure, few surgical procedures are equal in efficiency to the modern mastoid operation."

The dread with which a mastoid operation was often accompanied by the laity was not caused by the operation itself, but by the infection often already extending beyond the mastoid process into the petrous apex. The patients died because of the extent of the disease despite the mastoid operation, which was insufficient in petrositis. In the 1930s, several methods were published to deal with petrous apex pathology in connection with simple mastoidectomy (Kopetsky 1929, Eagleton 1931, Kopetsky and Almour 1931, Ramadier 1933, Lempert, 1937). The first use of sulphanilamide in 1935 tremendously reduced the serious complications of acute mastoiditis, especially the potentially fatal meningitis.

Incidence of Mastoidectomy

The introduction of penicillin after the second world war dramatically reduced the need for surgery, and the incidence of mastoidectomy decreased rapidly during the following years.

In the pre-sulphonamide era, 1–5% of patients suffering from acute suppurative otitis media required a mastoidectomy. The percentage is dependent upon the virulence of the organism, and different figures were seen in different epidemics (Glasscock and Shambaugh 1990). During the period 1947–1981, an annual incidence of 0.004% among cases with acute otitis was found in Finland (Palva et al. 1985). During this period, only 12 mastoidectomies for acute mastoiditis were performed. In one of the seven Copenhagen city Ear, Nose, and Throat departments (the Sundby Hospital), 236 mastoidectomies were performed in 1934, which projected would mean at least 1000 mastoidectomies per year in the Community of Copenhagen City, with 617,000 inhibitants. The decrease in the annual incidence is clearly illustrated in Figure **242**, and today in the same area the two Ear, Nose and Throat departments perform about five mastoidectomies per year.

In our department, covering a population of 350,000 inhabitants living in the northern half of Copenhagen County, mastoidectomy for acute mastoiditis is performed three or four times per year, which means that young otologists on duty will have to perform an acute mastoidectomy on children without having seen it before.

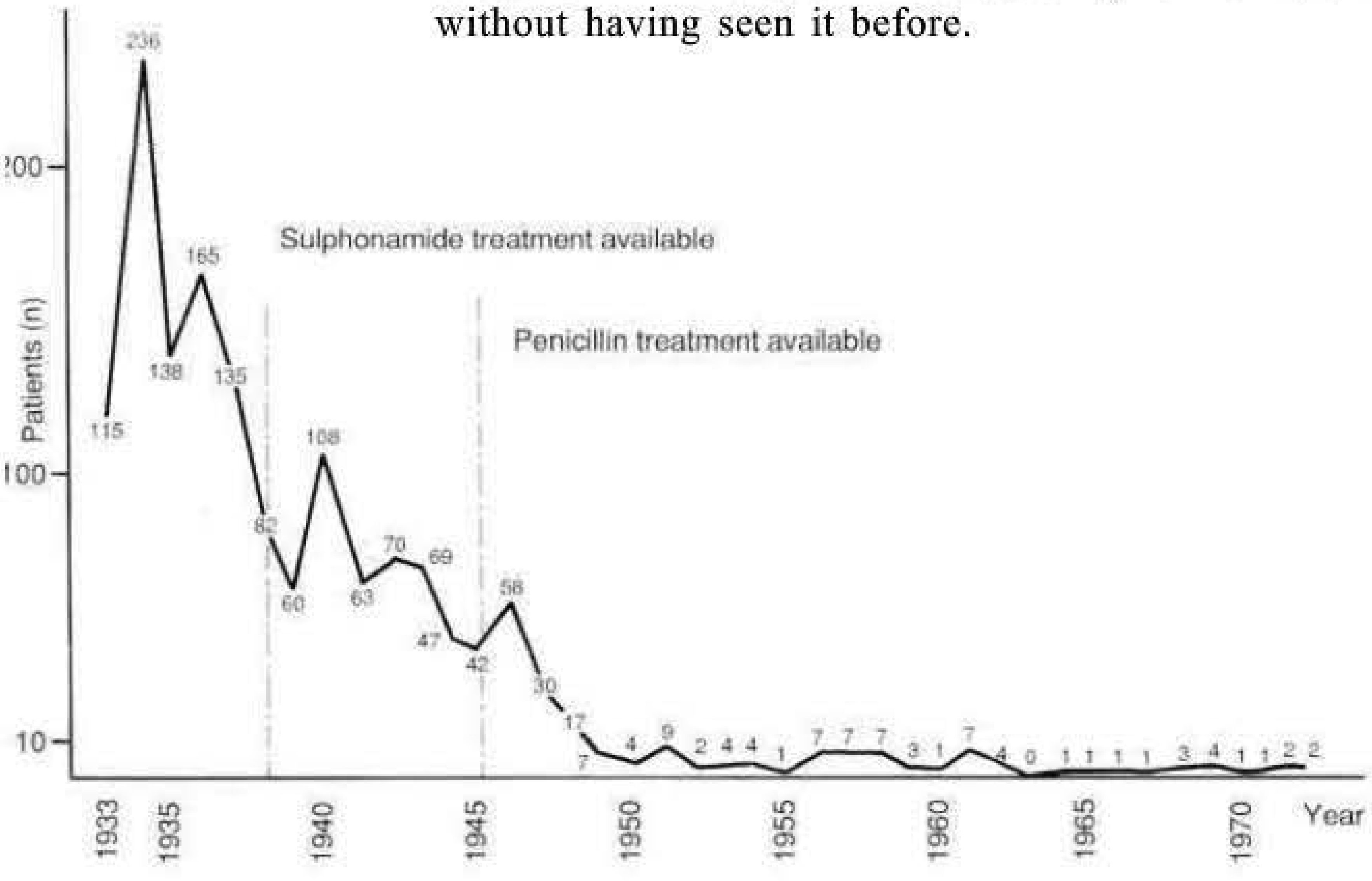


Fig. **242** Annual incidence of simple mastoidectomies for acute mastoiditis from 1933 to 1973 in the ENT department of Sundby Hospital, one of the seven ENT departments in Copenhagen city (courtesy of Dr. C. B. Pedersen, University of Aarhus)

Indications for Simple Mastoidectomy in Acute Mastoiditis

Today, there are few absolute indications and several relative indications for simple mastoidectomy. In fact, there is wide disagreement regarding the indications for mastoidectomy in acute mastoiditis. Generally, it can be stated that the simple mastoid operation is indicated for acute suppurative otitis media that fails to respond to antibiotic therapy and proceeds to coalescent mastoiditis. The questions arising from this are: What do we understand by failure of antibiotic treatment, and which clinical signs indicate a coalescent mastoiditis that has to be treated surgically?

Absolute Indications

1. *Retroauricular subperiosteal abscess* (Fig. **243**). Subperiosteal abscess is a result of extension of the coalescent mastoiditis onto the surface of the mastoid process. This extension usually occurs through the cribriform area behind the suprameatal spine. The tissues over the mastoid process are thick and red, due to the thickness of the periosteum and the subcutaneous tissue. Fluctuation is the best sign of an abscess, and although it may or may not be easy to detect initially, fluctuation can be demonstrated as the subperiosteal abscess matures.

2. *Zygomatic subperiosteal abscess.* Extension can occur, although less often, over the posterior root of the zygoma, producing a zygomatic abscess (Fig. **244**), elevating the periosteum under the lower edge of the temporalis muscle. The upper half of the auricle is displaced away from the skull and downward.

A very rare type of extension is from the cells of the root of the zygoma downward and forward into the mandibular fossa (Shambaugh 1941). The abscess appears just in front of the tragus, with displacement of the mandible to the opposite side, creating a malocclusion.

3. *Bezold abscess.* Extension through the medial aspect of the mastoid tip into the digastric grove produces the Bezold's abscess, situated deep in the neck, deep to the sternocleidomastoid muscle and the digastric muscle (Bezold 1908). The abscess does not reach the surface, and no fluctuation can be felt. There is moderate swelling around the lower end of the mastoid process. The suppuration can spread in all directions below the fascia of the neck, and may descend down into the superior mediastinum.

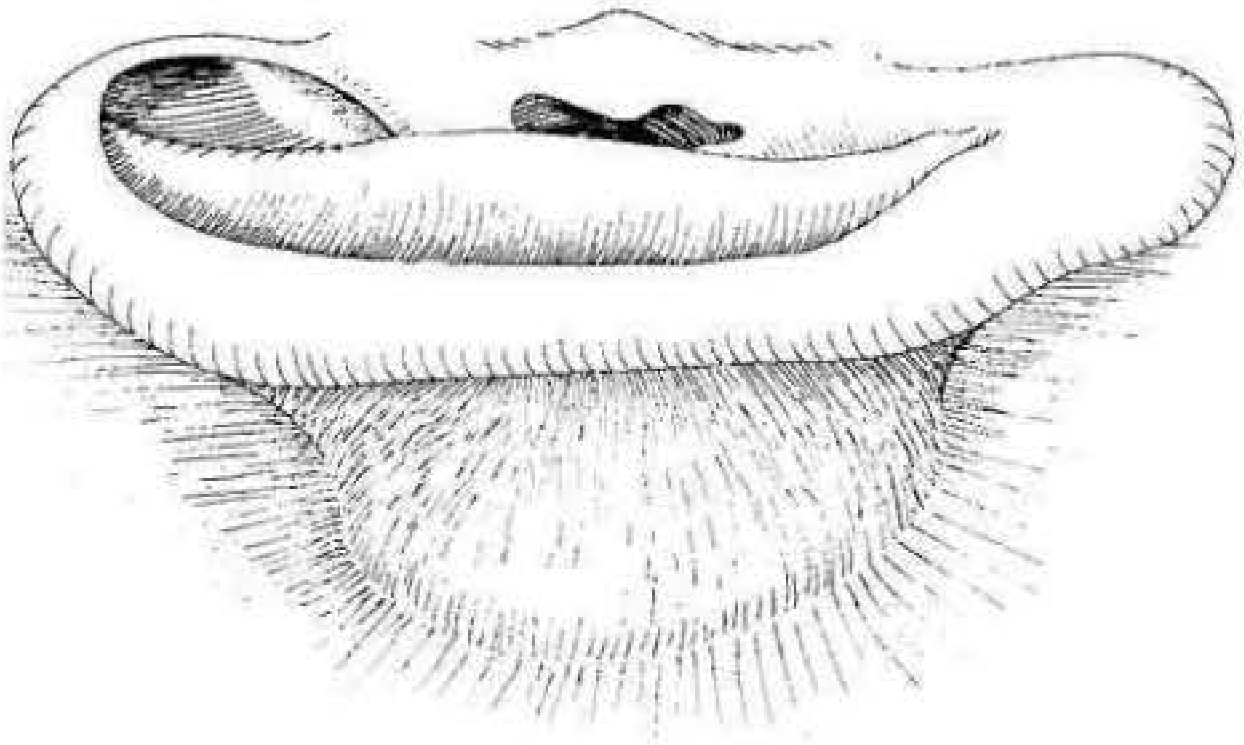


Fig. **243** **A retroauricular subperiosteal abscess** in acute mastoiditis developed behind the auricle. The abscess has displaced the auricle anteriorly

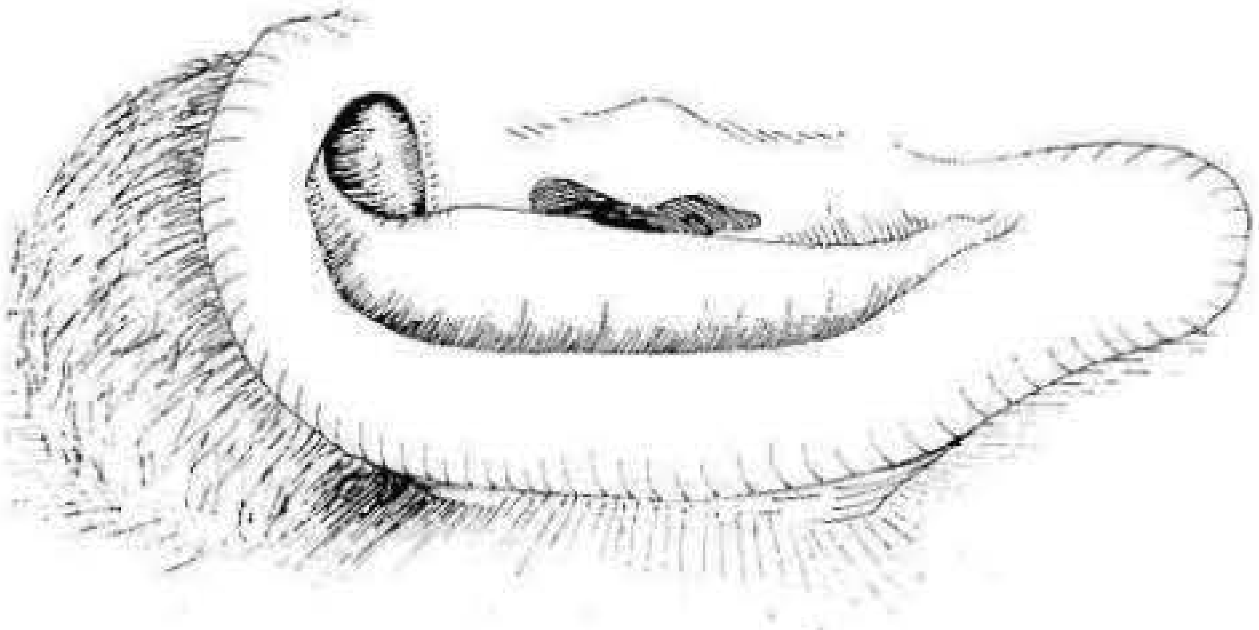


Fig. **244** **A zygomatic subperiosteal abscess** in acute mastoiditis, arising from the zygomatic cells. The auricle is displaced inferiorly

These various abscesses, even though they are rare, represent absolute indications for simple mastoidectomy.

Relative Indications

1. *Persistent pain* located behind the ear is a common symptom of coalescent mastoiditis due to the pressure of the inflamed tissue and restricted drainage. The pain increases when the patient is in the horizontal position. Severe pain suggests an *extradural abscess,* and a location deep behind the eye suggests a coalescent *abscess of the petrous apex. Persistence* of pain for longer than two weeks after the onset of acute otitis media is a relative indication for surgery, as is *recurrent pain* occurring several weeks after painless discharge in acute otitis.

2. Persistent *tenderness over the mastoid process* is the most consistent physical sign of coalescent mastoiditis. Even though tenderness may be

considerable in the first few days of acute otitis, it is not an indication for surgery, but if it persists after several weeks, it points toward a coalescing process.

3. *Sagging* of the posterosuperior meatal wall due to thickening of the periosteum near the antrum. Sagging can occlude the external meatus.

4. *Periosteal thickening* over the lateral surface of the mastoid process is caused by edema in a mastoid abscess approaching the lateral surface of the mastoid process.

5. *Persistence of a profuse, creamy aural discharge* for more than four weeks in acute suppurative otitis media is a symptom of a coalescent process in the mastoid, but the author prefers to continue with antibiotics and local treatment in the form of daily cleansing of the ear with saline and instillation of ear drops for some few weeks more before surgery.

Recent studies on acute mastoiditis in children have concluded that, in the absence of subperiosteal abscess or central nervous system involvement, a 48-hour trial of intravenous antibiotic therapy directed against staphylococci is justified before mastoidectomy is considered (Nadal et al. 1990, Prescut and Mallan 1991).

Simple Mastoidectomy Technique in Infants

In infants, the mastoid process is not yet developed, the cortical lamina is thin, and infantile mastoiditis with subperiosteal abscess appears relatively early after the onset of acute otitis. The spread of pus onto the surface of the mastoid process passes along the vessels through the relatively patent cribriform area.

Before the incision, a myringotomy and grommet insertion is performed in the anterosuperior quadrant of the drum. These procedures are carried out through an ear speculum.

The retroauricular incision runs 0.5–1.0 cm behind the retroauricular fold. The incision ends somewhat higher than the usual retroauricular incision, to avoid trauma to the facial nerve and the parotid gland (Fig. **245**). Usually, the incision passes through the subperiosteal abscess on the way down to the cortical bone. Passing through the subperiosteal abscess onto the surface, small holes within the cribriform area of the cortical bone are sometimes recognizable, with pus coming out from the depths (Fig. **246**). By following these holes, the antrum is found after removal of the soft cortical bone with a sharp curette or a cutting burr.

Before drilling, the granulation tissue and the periosteum surrounding the abscess is removed, and

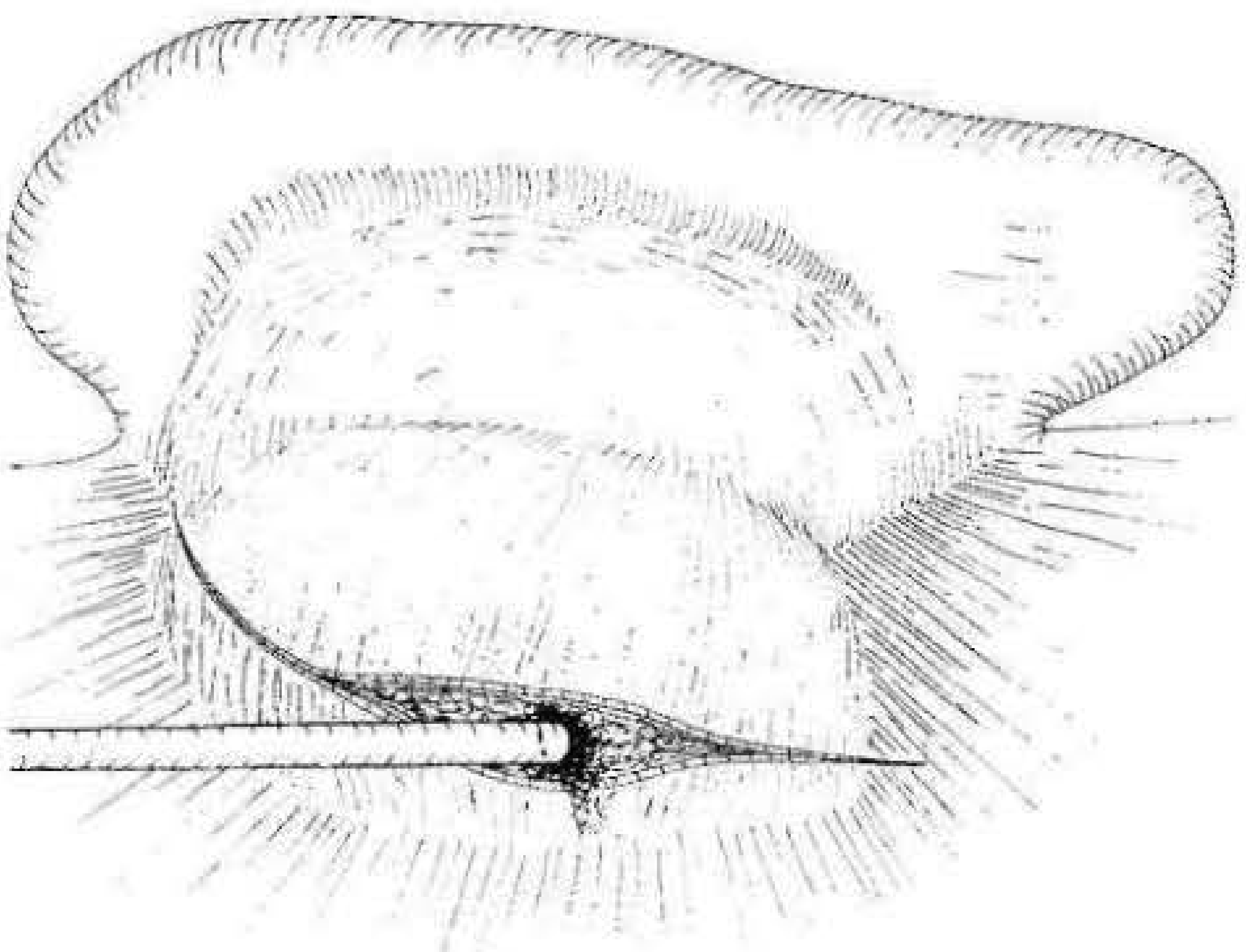


Fig. **245** **Simple mastoidectomy in infants.** The incision is placed over the top of the subperiosteal abscess, 0.5–1.0 cm behind the postauricular fold. It is directed more posteriorly, avoiding the stylomastoid region, the parotid gland, and the facial nerve. The incision ends at the tip of the mastoid process, which in infants is considerably shorter than in older children. Pus is taken for bacteriological culture and then suctioned away

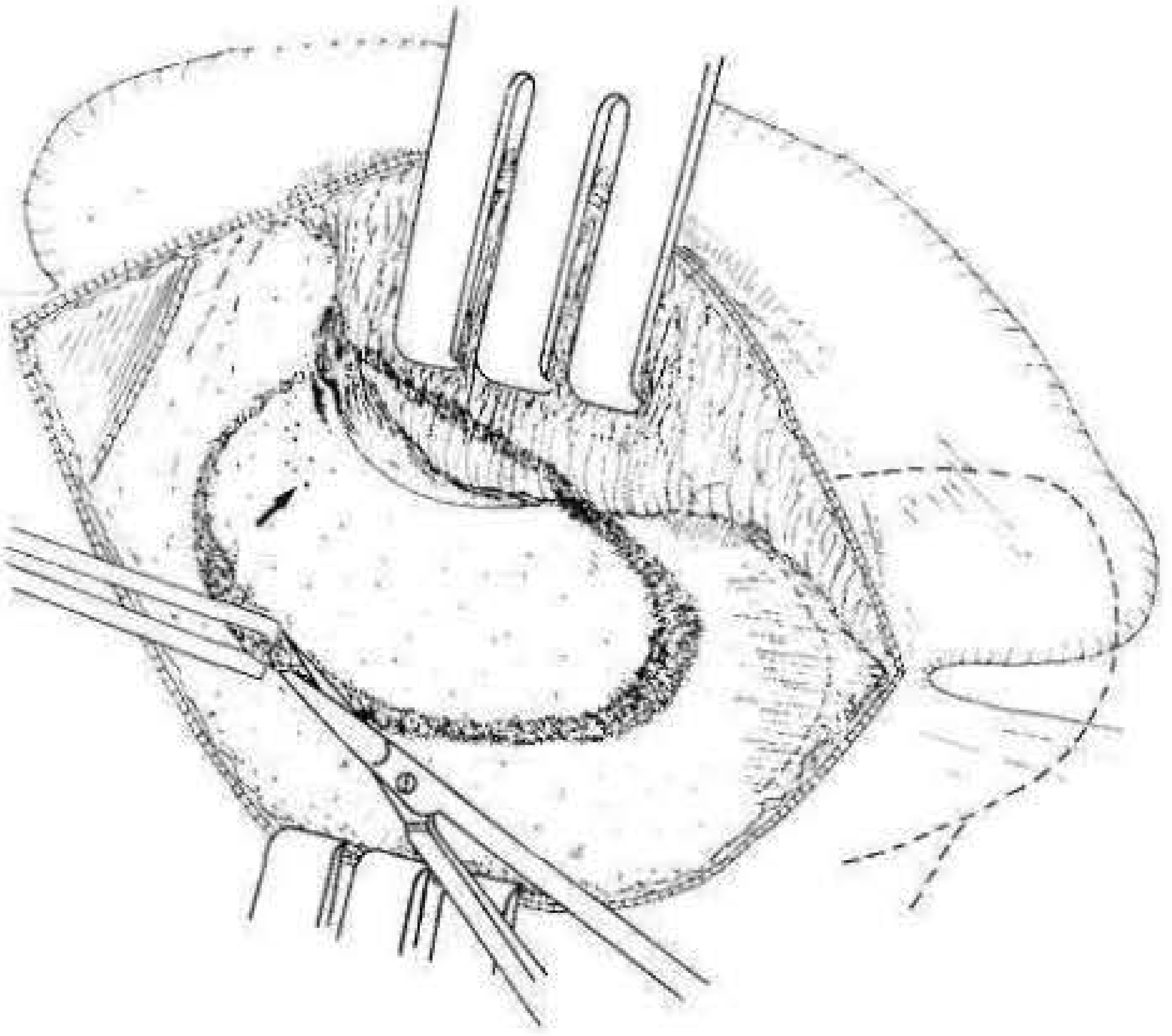


Fig. **246** The periosteum and the granulation tissue surrounding the subperiosteal abscess are elevated from the mastoid cortex and excised. The cribriform area is indicated behind the suprameatal spine (arrow). The ear canal skin is not elevated. The mastoid process is short in comparison with older children, as indicated by the dashed lines

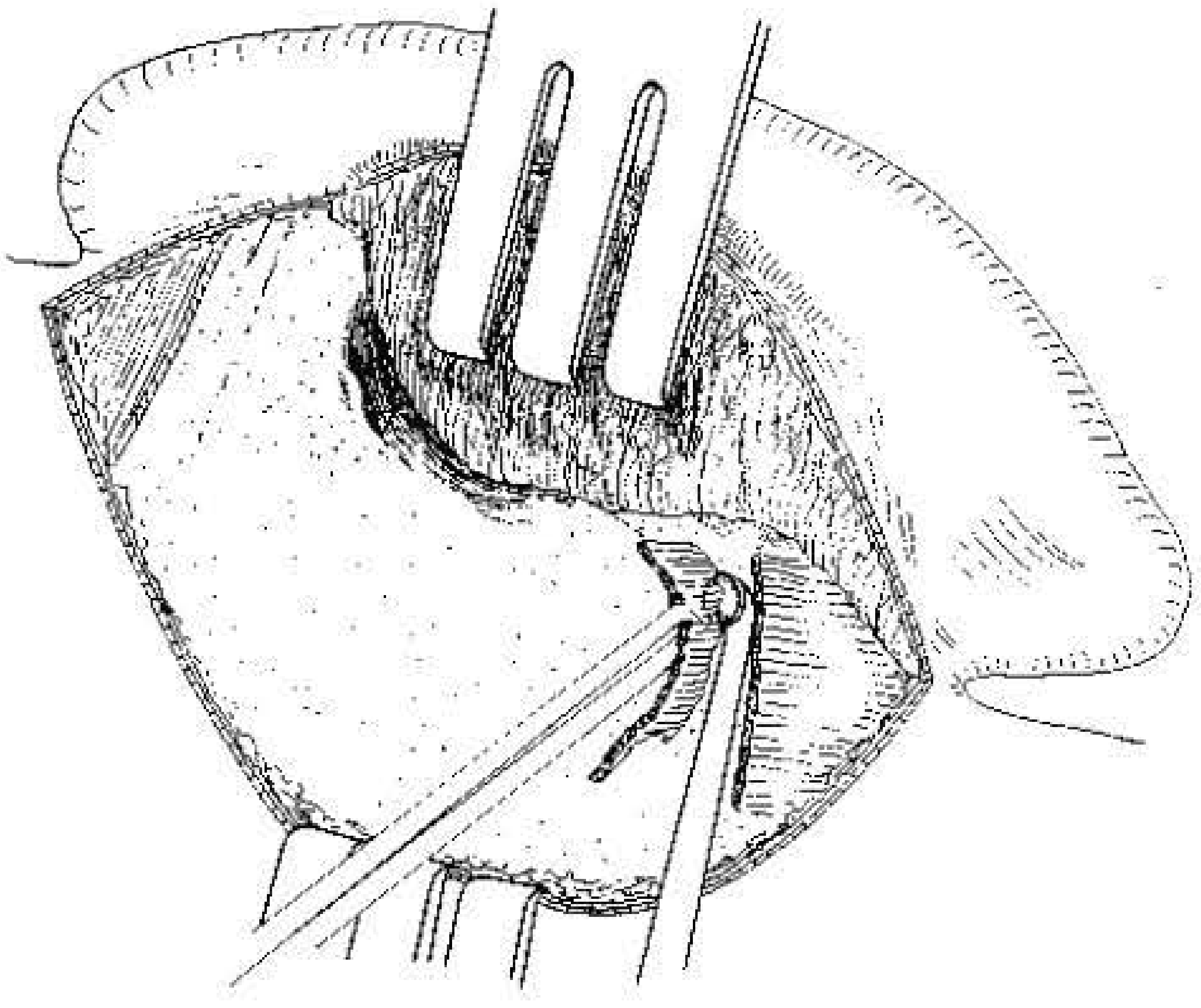


Fig. **247** Incision over the inferior part of the mastoid process at the attachment of the sternocleidomastoid muscle, and exposure of the cortex. The periosteum and the granulation tissue is removed, and the mastoid cortex is cleaned

the surface of the mastoid process is cleaned (Fig. **246**). The pus is sent for bacterial culture, using either a swab or aspiration. The fibers of the sternocleidomastoid muscle attached to the surface of the mastoid process are cut with a knife, and elevated together with the granulation tissue from the subperiosteal abscess. All the granulation tissue around the abscess is cleared, and the cortical bone is widely exposed (Fig. **247**). The ear canal skin is not detached from the bone; only the suprameatal spine and the most lateral border of the ear canal are located.

Drilling should be performed using a microscope at low magnification. Starting behind the suprameatal spine and following the holes of the cribriform area, the thin and sometimes soft cortical lamina is gently drilled using a sharp burr, exposing the necrotic cell septa, which are removed with a curette together with any granulation tissue (Fig. **248**). The cortical lamina is further removed, exposing the lateral wall of the mastoid process, the necrotic cell septa are again removed with a curette (Fig. **249**), and after gradual removal of the septa, the antrum is opened (Fig. **250**). After removal of any bony overhangs and septa from the middle fossa dura plate and further removal of the accessible periantral cells, the simple mastoidectomy is completed (Fig. **251**). There is no need to remove all the mucosa, even if it is swollen. It is important to clear the coalescent foci and open the septa of the cells. In infants, there will be no air cells in the inferior part of the mastoid process, only bone marrow. The lateral semicircular canal on the medial wall of the antrum is visible, and no attempt is made to clean

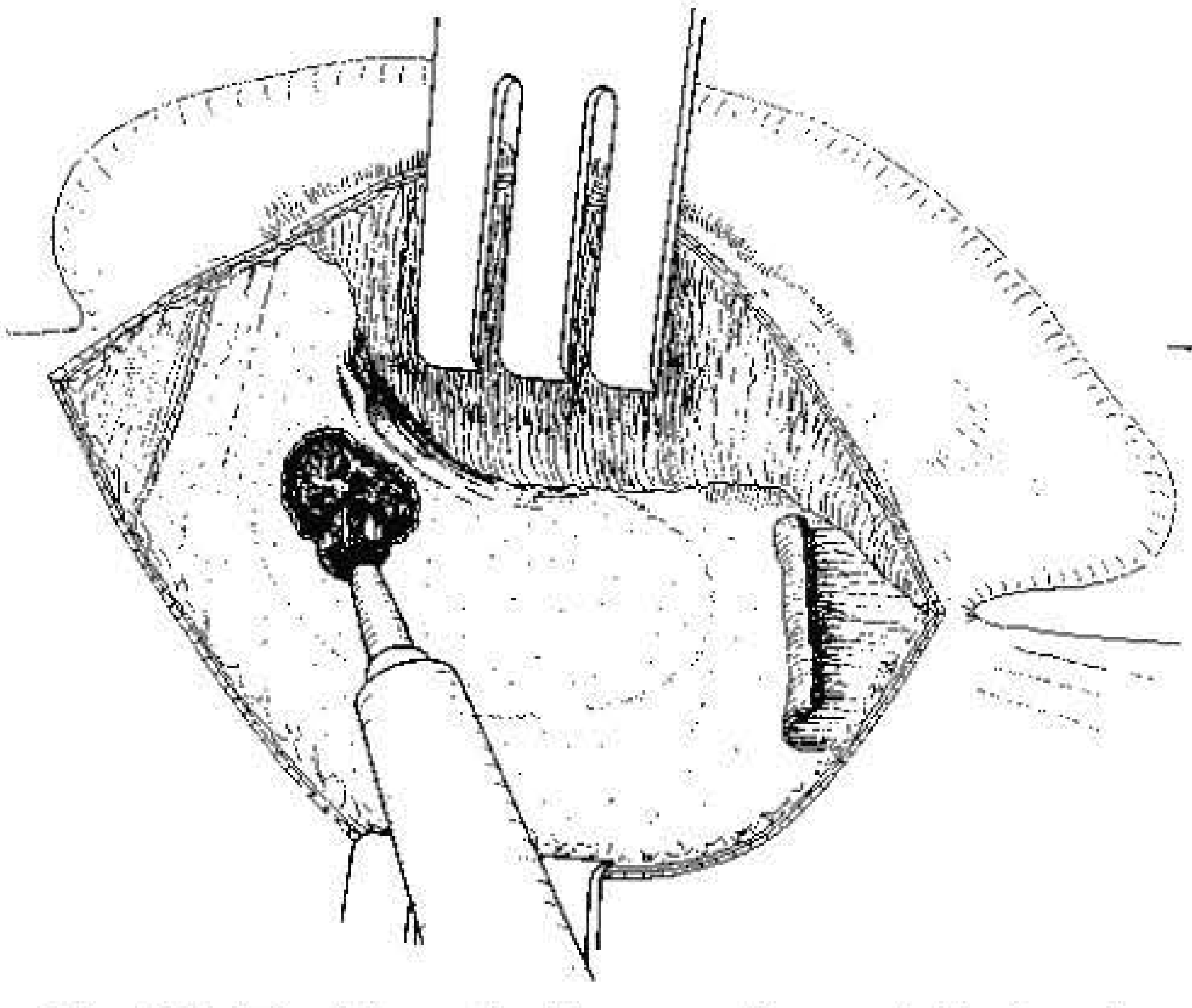


Fig. **248** The thin cortical bone on the mastoid plane is carefully removed using a large, sharp burr, and the underlying granulation tissue and necrotic bone becomes visible

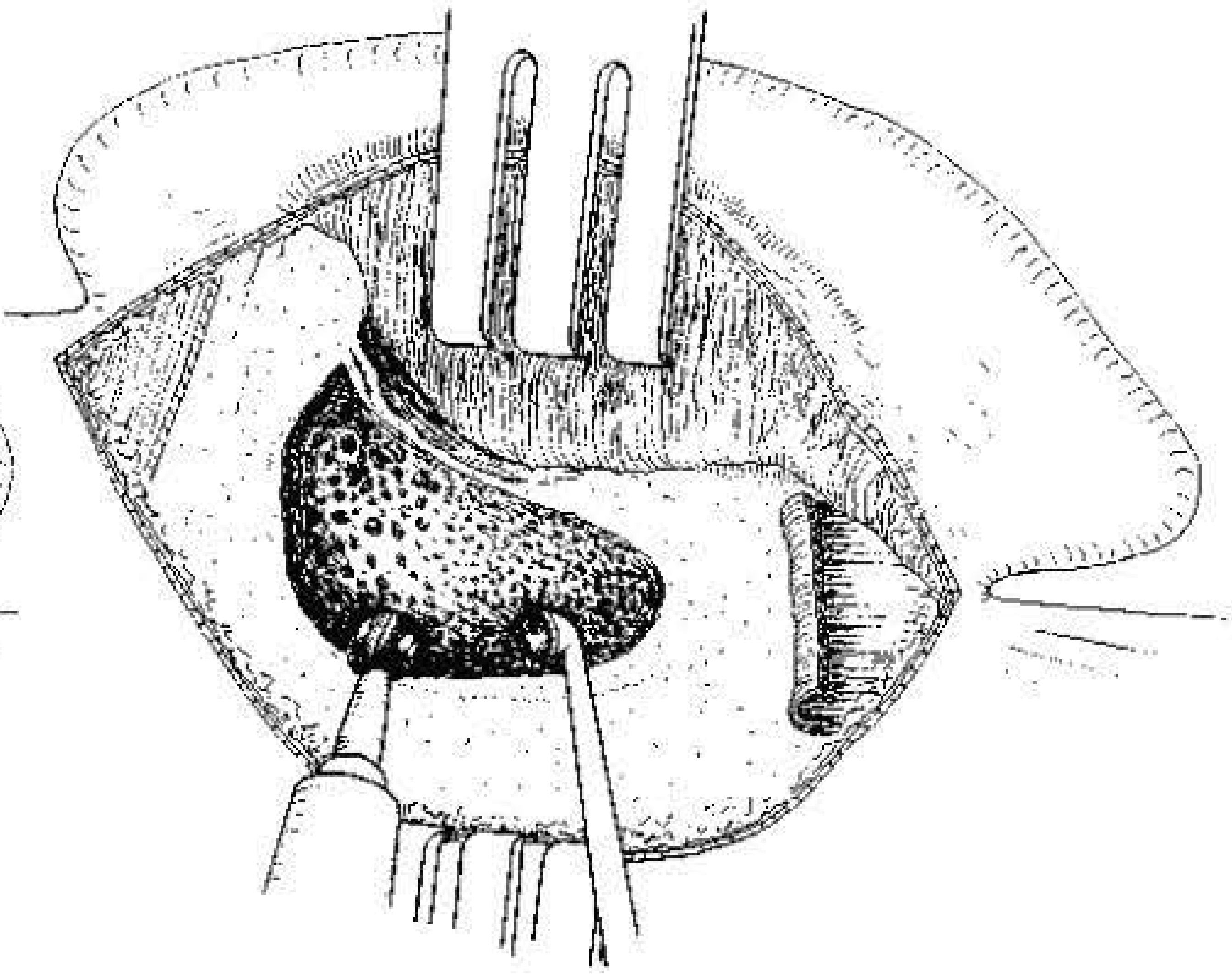


Fig. **249** The cortical bone is gradually removed using a cutting burr, and the lateral mastoid air cells are exenterated using a large curette

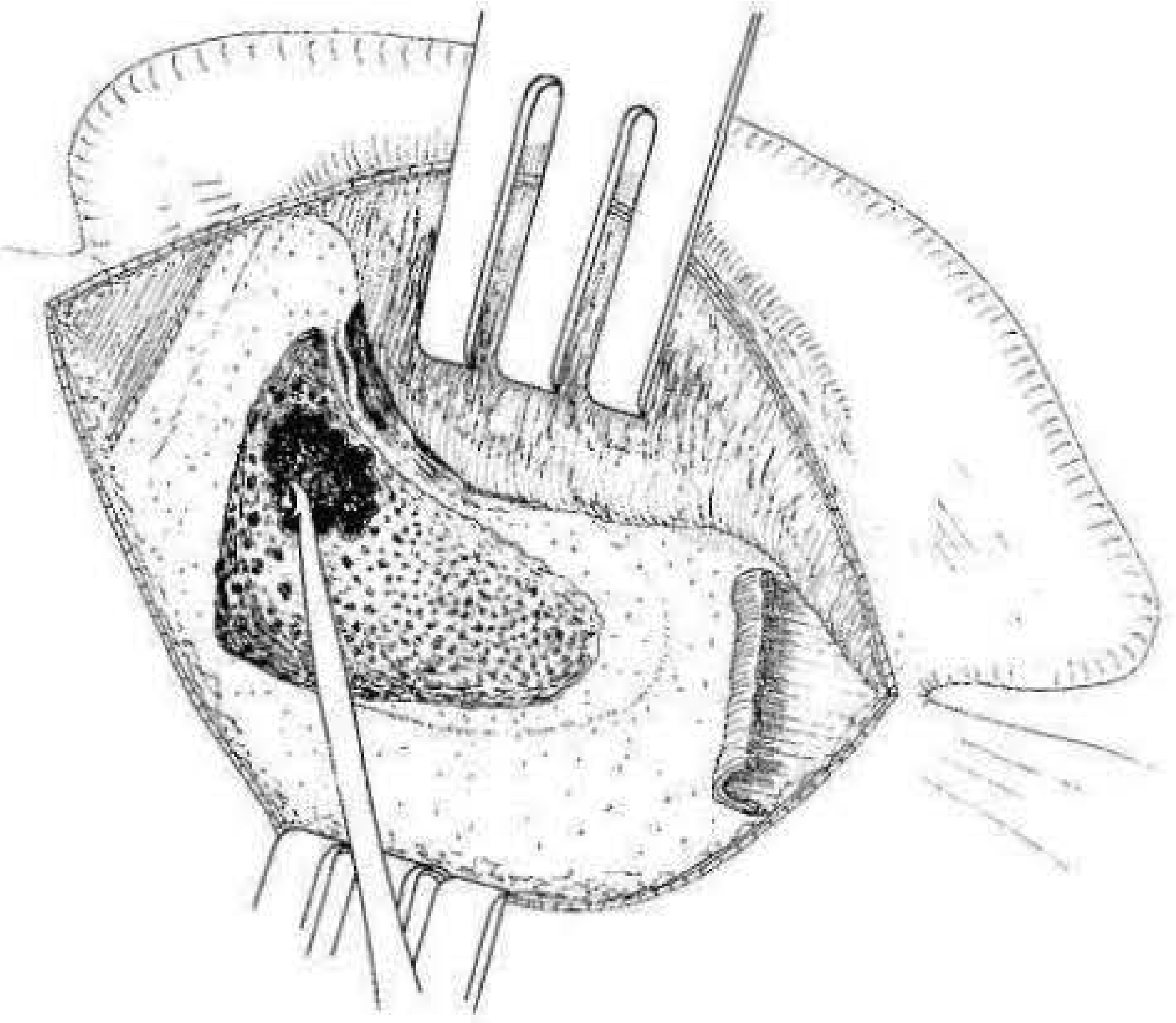


Fig. **250** After further opening of the cells and removal of the cortical lamina, the mastoid antrum is carefully opened using a curette and elevating the cell septa. The antrum is cleaned, and Körner's septum is removed

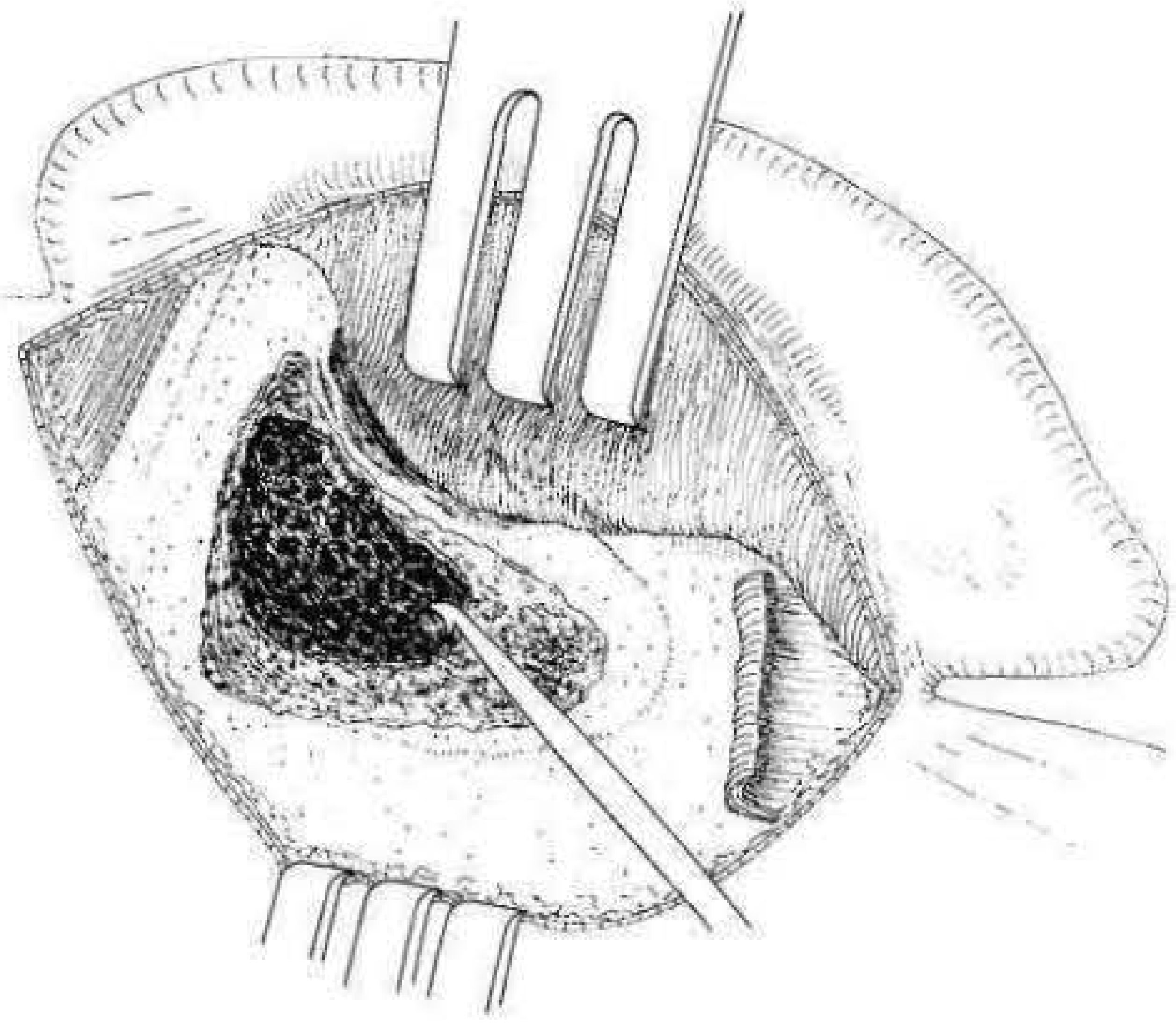


Fig. **251** Körner's septum has been removed using a curette, and the antrum has been opened further. All accessible cells are opened and the overhangs are cleaned using a curette, but the mucosa is widely preserved

the attic. The mucosa of the attic surrounding the ossicles should not be touched.

The mastoid cavity is cleaned with saline. If grommet insertion has been performed before the mastoidectomy (which is recommended), then the water passes through the aditus, attic, tympanic cavity, and grommet into the ear canal, indicating free drainage.

As well as the ventilation tube placed in the drum to ventilate and drain the tympanic cavity, the author recommends placement of a thick plastic tube in the antrum. The tube is pulled through a small, separate skin incision (Fig. **252**), using a surgical clamp, and then sutured to the skin (Fig. **253**).

The wound is closed with Dexon sutures (polyglycolic acid), including the intact part of the periosteum superiorly and inferiorly, as well as the subcutis. At the lower end of the wound, a piece of thin rubber drain is placed, which is fixed with a suture and removed the next day. The skin is then closed with nylon sutures (Fig. **253**).

The thick plastic tube acts as a ventilation tube for the mastoid process, but antibiotics can also be instilled through the tube. Portmann (1979) places twin plastic tubular drains into the mastoid cavity for similar irrigation purposes.

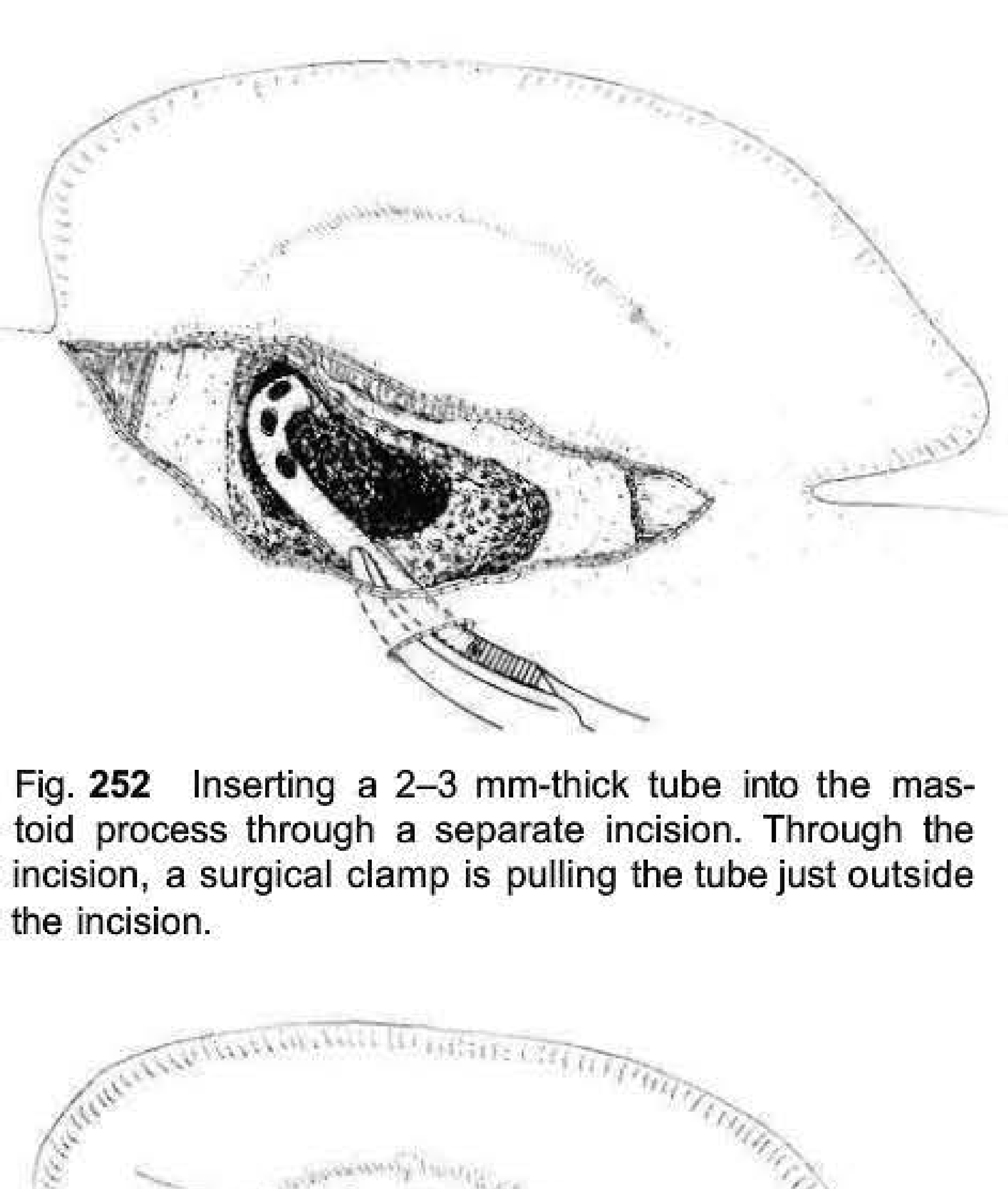


Fig. **252** Inserting a 2–3 mm-thick tube into the mastoid process through a separate incision. Through the incision, a surgical clamp is pulling the tube just outside the incision.

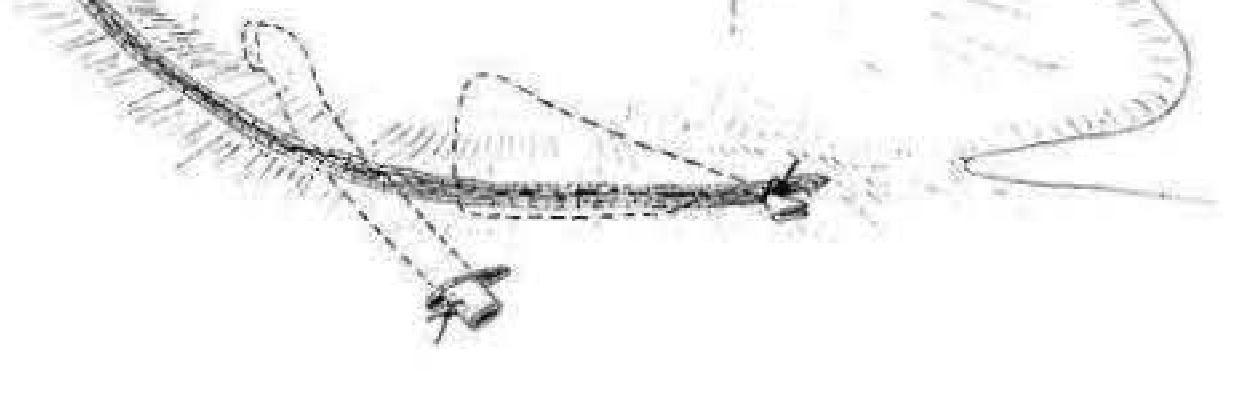


Fig. **253** The tube is fixed to the skin, and can be left in ▷ place for about three weeks after the operation. Its functions mainly for ventilation of the mastoid process. At the lower end of the incision, a piece of thin rubber taken from a surgical glove is placed in the cavity draining the inferior part of the cavity. This drain is removed on the day after the operation

Postoperative Care

As soon as the patient is conscious, the facial movements are examined to exclude operative damage to the facial nerve. Antibiotic therapy is continued, and local decongestants are added to promote drainage of the middle ear cleft via the Eustachian tube. The patient is kept on a four-hourly temperature chart. The temperature usually falls dramatically within the first 24 hours. The patient can be discharged two or three days after surgery. The rubber drain is removed the next day, the sutures after one week, and the thick plastic tube three weeks after the mastoidectomy. An audiogram should be performed within one month of surgery if possible, but if not, hearing should be evaluated using tuning forks.

Cortical Mastoidectomy Technique in Older Children

In children over two years, the mastoid process has enlarged, and is usually pneumatized. In ears with a large pneumatic cell system, the mastoidectomy technique does not essentially differ from the cortical mastoidectomy described in Chapter 4. The principle is to open all accessible air cells, and of course remove all the foci of mastoiditis if mastoiditis is the indication for the operation. However, the constant change in the size of the mastoid air cells during childhood should be taken into consideration when performing mastoidectomy in children.

The Size of the Mastoid Air Cells and Mastoidectomy

The mastoid air cells develop after birth. The first are the periantral cells, gradually followed by the mastoidal, tegmental, perilabyrinthine, and apical cells. This development continues parallel to the growth of the mastoid process. In infancy (before the age of one), the mastoid process is not fully developed. During the second year, the mastoid air cells increase in size, but very slowly, and their planimetric area is still very small at two years (Fig. **254**). Mastoidectomy for acute mastoiditis should therefore be performed very carefully in patients under two years old, applying the principles described for mastoidectomy in infancy to avoid facial palsy and incus dislocation. After the age of two, the size of the air cells increases, and the principles of mastoidectomy described for adults can be applied (Figs. **127–130**). The tegmental cells are exenterated (Fig. **147**), and the sinodural cells are opened (Fig. **148**). The perisinosal cells are then exenterated (Fig. **149**) using a large diamond or cutting burr and progressing in an inferior direction (Fig. **150**). Further drilling toward the apex follows the direction of the sigmoid sinus.

Entering the Mastoid Antrum

When searching for the mastoid antrum, it should be remembered that it is located just above and behind the posterosuperior bony meatal wall, a few millimeters lateral to the bony annulus and tympanic sulcus. The best way to enter the antrum is to follow a cell from Körner's septum in an anterosuperior direction (Fig. **189**) and gradually remove the plate of Körner's septum (Figs. **190, 191**). In small children, Körner's septum is not usually thick, and widening of the first cell will open up the antrum. This is carefully enlarged by further removal of the cells superiorly and posteriorly, either with a burr or a curette. In mastoiditis with coalescent foci and granulations, a curette is recommended instead of a drill (Figs. **250, 251**).

Exenteration of the cells continues toward the tip of the mastoid process, following the course of the sigmoid sinus (Figs. **192, 193**). Drilling of the sinodural angle and exenteration of the cells is carried out with a diamond burr (Fig. **197**). Finally, the exenteration of the mastoid tip cells is performed (Fig. **207**).

In a case of coalescent mastoiditis within the mastoid tip and extension into the medial part of the mastoid tip, below the digastric crest, these cells have to be exenterated too, which in small children is most safely performed with a curette (Figs. **210, 211**), with care being taken to avoid damage to the vertical portion of the facial nerve.

The cortical mastoidectomy is now completed, and by following the procedure step-by-step, a complete mastoidectomy can be performed. This includes: 1) exenteration of all mastoid cells; 2) removal of cells from the mastoid tegmen and sinodural angle; 3) opening and removing the perisinosal cells; 4) opening and removing the lateral apical cells from the mastoid tip, especially the largest cells; 5) opening the antrum and removing the periantral cells, as well as some perilabyrinthine cells; and 6) exenteration of the medial apical cells.

It is also important to remove the zygomatic cells, if they are present, without entering the attic. Surgery in the attic region is not part of a simple mastoidectomy, nor is surgery in the facial recess.

In a case with extension of the infection through the medial cortical lamina of the mastoid tip and formation of a Bezold abscess, complete removal of the

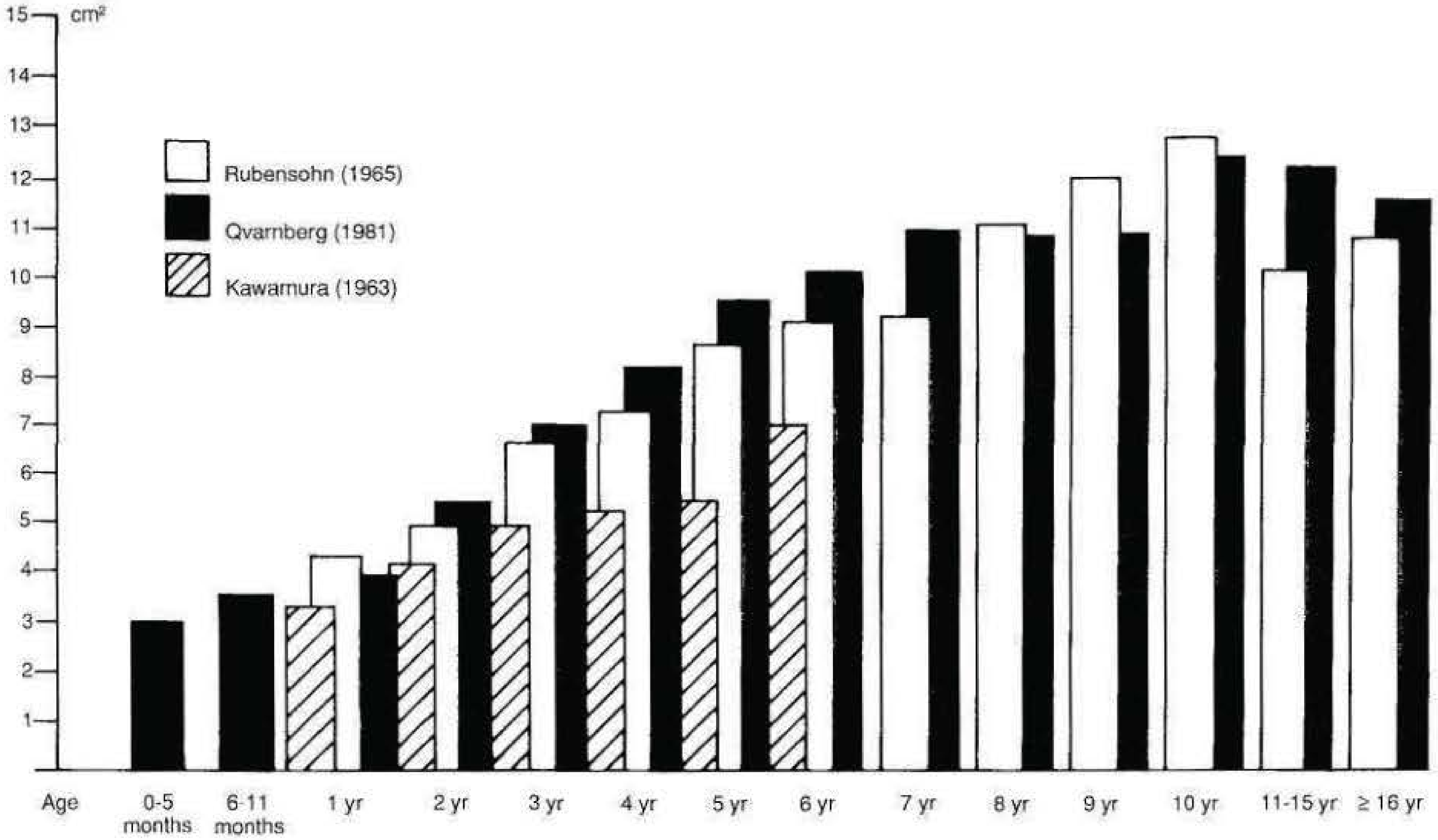


Fig. **254** The average size of the mastoid air cell system in various age groups during childhood in three study groups

mastoid tip is necessary. These techniques are described in Chapter 16 (pp. 315–320).

Complications of Cortical Mastoidectomy

Simple mastoidectomy for acute mastoiditis will usually be performed as an acute operation by a junior otologist, who has probably never performed an acute mastoidectomy before. Complications can therefore be expected to be higher than in elective mastoid surgery.

Facial paralysis is the most important complication, and results from an injury to the facial nerve. It can occur with a trained otologist, but usually it is a fully trained occasional surgeon who is involved when there is a facial nerve accident. When performing mastoidectomy in infants, the risk of causing accidental facial paralysis is high due to the relatively superficial position of the nerve in an undeveloped mastoid process. If the paralysis occurs immediately after the operation, exploration with decompression and inspection of the facial nerve and eventually nerve grafting should be performed as soon as possible, and no later than 24 hours after the surgical trauma. If the paralysis is partial, or delayed acute surgery is not necessary, the proper treatment will depend on the clinical course and the results of electromyographic investigations showing possible degeneration of the facial nerve.

Injuries to the sinuses (sigmoid sinus, superior petrosal sinus and jugular bulb) are described in Chapter 4. They cause profuse bleeding, but this can be controlled by placing a piece of Surgicel onto the leak and holding it against the sinus with a cottonoid for several minutes.

Injury to the dura can happen especially in infants and small children. Methods of avoiding injury to the dura and its management are described in Chapter 4.

Subluxation of the incus after manipulation in the attic with a sharp drill, tip of the suction tube, or curette. Subluxation may remain unrecognized in infants and small children, and is sometimes only discovered when the child is at school age, after the mastoiditis has healed. Regular audiograms in older children and investigation with tuning forks in small children, as well as other hearing tests, should be performed one month after surgery.

Extraction of the incus can occur when a curette is used in the attic for removal of granulations.

Traumatic high tone loss for the frequencies 4000 and 8000 Hz has been a very common finding after previous mastoidectomy in childhood. This is caused by excessive movements of the ossicular chain, either with the suction tube or other instruments.

Anakusis can occur due to excessive movements of the stapes, similar to anacusis found after traumatic incus subluxation, which we found in cases with longitudinal temporal bone fractures combined with an incus subluxation (Tos 1971).

Late Sequelae after Mastoidectomy

Meatal stenosis, located at the entrance of the external acoustic meatus, caused partly by new bone formation at the posterior edge of the bony ear canal wall and partly by fibrosis of the external meatus, may occur. Usually, a combination of both factors is found, especially if the ear canal skin has been elevated and the periosteum of the meatus damaged. Sometimes in adults, the smallest speculum can hardly pass the stenosis. The medial part of the ear canal is normal in size. The patients have cerumen problems, and may later have problems with a hearing aid.

Bony fixation of the malleus and incus is the most common cause of late hearing loss after mastoidectomy. Because of manipulation in the narrow attic, adhesions between the attic walls and ossicles may occur, and sometimes bony fusion between the anterior and superior attic wall and the malleus head takes place. Also, fusion between the incus body and the lateral semicircular may occur. In a series of bony fixations of the malleus and incus, the most common cause was previous mastoidectomy or atticoantrotomy (Tos 1970, Tos 1974 a).

Indications for Cortical Mastoidectomy other than Coalescent Mastoiditis

Currently, there is dispute over the indications for mastoidectomy in cases of subchronic, chronic, or recurrent acute discharge. Another contentious area is how radical one should be in the removal of mucosa in mastoiditis. The goal of acute mastoidectomy is to remove the coalescent tissue from the mastoid process and to prevent spread of the disease through the middle and posterior cranial fossa dural plates to the cranial fossae themselves. These goals are currrently being achieved, especially with the concomitant support of antibiotics. In the present author's opinion, therefore, mastoidectomy for simple mastoiditis should today not be too aggressive to the mastoid process mucosa. The postoperative goal is to achieve good pneumatization of the mastoid process, and for this the mucosa is required. Another goal is to interfere with the pneumatization process, and requiring as little growth of the mastoid process as possible, and for this purpose healthy mucosa is needed. If pathological mucosa is left in situ, it will eventually normalize, and the pneumatization process can continue. If the mucosa has been totally removed, it may take a long time before new mucosa lines the cavity, and the pneumatization process is thus hampered for a longer period. The indications for cortical mastoidectomy are detailed below.

1. *Grommet discharge in chronic cases of secretory otitis media.* Some postgrommet discharge is common, and its incidence varies between 10 and 30% in the literature (Tos 1990 b). In most cases, the discharge is insignificant, and stops spontaneously after some days, or after instillation of drops containing antibiotic and hydrocortisone. In infants and small children, the discharge can continue for one or two months, despite systemic antibiotics and local treatment. The question of mastoidectomy arises in such cases. The present author removes the grommet (and the granulation tissue surrounding it) after two months, and if the discharge persists, treats the patient with appropriate antibiotics as well as local treatment, i. e., cleansing of the ear canal followed by ear drops once daily, for an additional three months before considering cortical mastoidectomy. Also, a second course of antibiotic treatment with a broader-spectrum antibiotic is tried. Usually, the child is hospitalized for a week in order to provide effective local treatment and intravenous antibiotic treatment in order to get the ear dry without mastoidectomy. In the majority of cases, the ear stops discharging, and spontaneous closure of the perforation occurs. If there is a recurrence of secretory otitis media, a new grommet can be inserted, and the middle ear ventilated. We rarely perform mastoidectomy in such cases, but if mastoidectomy is performed, swollen, secretory mucosa as well as mucus is found in the mastoid process, but no coalescent foci or aditus block. The mucus is removed, the cells are opened, and the mucosa of the septa is removed. A thick ventilation tube is placed in the antrum. The swollen mucosa in the attic may imitate obstruction, but the tympanic isthmus remains open and mucociliary transport to the tympanic cavity is provided via this route. Removal of the attic mucosa in order to improve the connection between the antrum and the tympanic cavity is not recommended. This type of enlargement creates other problems, such as a risk of high tone sensorineural hearing loss, adhesions, and new bone formation.

Some surgeons (Palva et al. 1964, Fleischer 1979, Crabtree 1985) are offering mastoidectomy after only one month of conservative treatment on the grounds that the mastoid process is filled with mucus and that the operation helps to make the ear dry. It is not documented whether an early or a late mastoidectomy is better.

2. *Protracted secretory otitis media, atelectasis, aditus "block."* Some surgeons perform mastoidectomy in cases of protracted secretory otitis media with recurrent accumulations of fluid and hearing loss and recurrent spontaneous extrusions of the grommets. Severe cases of atelectasis with recurrent hearing loss may be added to this group. An aditus "block" (Proctor 1971) is proposed as the cause of such conditions, and a cortical mastoidectomy should therefore provide relief.

In the author's opinion very little has been written about the "aditus block," and there is no documentation on the long-term benefit of mastoidectomy compared to repeated insertion of ventilation tubes, especially using longer-term tubes. The author therefore has reservations regarding cortical mastoidectomy in such cases.

3. *Recurrent acute otitis media.* Cortical mastoidectomy was formerly recommended (Palva et al. 1964) in younger children with frequent attacks of otitis in order to break the vicious cycle. In cases with recurrent otitis media, we have performed prophylactic insertion of ventilation tubes, and have reduced the number of acute otitis episodes to one-seventeenth of the preoperative number. Fifty-five per cent of children have had no episodes, and 24% one or two episodes only, and no mastoidectomies have been performed in this series (Bonding and Tos 1976).

4. *Meningitis and acute otitis.* In general, there are two views on this problem, with the first group being much more surgically aggressive than the second. The first group of surgeons perform paracentesis in all cases of meningitis, even with only the slightest suspicion that an acute otitis may be present. This group also advocates acute mastoidectomy in children with acute otitis and meningitis. The other group, including the author, does of course perform paracentesis in cases of purulent acute otitis, but does not perform an acute mastoidectomy in a child with meningitis and no evidence of coalescent mastoiditis or subperiosteal abscess. The drainage of the ear through the drum and the massive adjuvant antibiotic treatment of meningitis should be sufficient to cure the acute otitis and avoid the risk of surgery in children with acute meningitis.

5. *Exploratory cortical mastoidectomy.* Sometimes an exploratory mastoidectomy is performed to exclude tumor or other severe pathology in specific cases—for instance in acute facial palsy and middle ear pathology, suggesting the presence of a tumor along the vertical course of the facial nerve.

The literature on acute mastoiditis and mastoidectomy from the 1980s and 1990s clearly demonstrates that, due to penicillin and other broad-spectrum antibiotics, the incidence of mastoiditis requiring hospitalization is low, and the majority of patients treated for mastoiditis being cured by antibiotic treatment alone. All series published show small percentages of cases being "mastoidectomized," and patients with postauricular erythema or edema without clear evidence of subperiosteal abscess have not been operated on, indicating that acute mastoidectomy can in most cases be postponed for one or two days, awaiting improvement after intensive antibiotic treatment. This also means that acute mastoidectomy, when required in some cases, does not need to be extensive, and that the mucosa can be widely preserved, especially in the attic and aditus ad antrum.

A questionnaire among all ENT departments in Denmark, with a population of 5.1 million, showed that a total of 40–50 mastoidectomies were performed per year in children for an acute disease (Table **5**). The most common indications were acute mastoiditis and recurrent acute otitis (Rasmussen 1986, 1994).

Table 5 Indications for simple mastoidectomy in Denmark based on a questionnaire among all danish ENT departments during the periods 1980–1985 and 1990–1993

Indications	Number of acute mastoidectomies									
	1980	1981	1982	1983	1984	1985	1990	1991	1992	1993
Mastoiditis	25	27	21	26	28	38	11	25	17	16
Recurrent acute otitis	21	6	19	13	19	4	6	5	6	7
Acute meningitis	1	0	2	3	0	2	7	6	5	2
Other indications	3	3	1	5	2	3	11	9	11	15
Total	50	36	43	47	49	47	35	45	39	40
No. of ENT dept.	23	23	23	23	22	21	21	21	21	20

6 Classic Intact Canal Wall Mastoidectomy

Definition

The characteristics of the classic intact canal wall mastoidectomy are:

1. A retroauricular approach and transcortical route (Fig. **24**). The operation can begin with an endaural approach in order to perform surgery in the tympanic cavity, but an intact ear canal can only be maintained through the retroauricular approach. The endaural approach does not allow sufficient exposure of the attic through the mastoid when the bony ear canal wall is intact.
2. An entirely intact, but thin, posterosuperior bony ear canal wall. In cases with attic cholesteatoma and spontaneous erosion of the lateral attic wall (frame or scutum), the superior ear canal wall cannot be preserved completely intact. However, in such cases the eroded part can be reconstructed by bone, cartilage, or other materials.
3. A posterior atticotympanotomy (Jansen's posterior tympanotomy) through the facial recess, allowing exposure of the posterior tympanic sinuses.
4. Drilling laterally into the root of the zygoma, exposing the tendon medially as well as part of the tensor tympani muscle and the tympanic orifice of the eustachian tube (Jansen 1963, 1968).
5. Reconstruction of the ear drum at the level of the bony annulus.
6. Re-aeration of the attic, antrum, and mastoid process through the enlarged attic and facial recess.

Because the procedure *combines* the concept of tympanoplasty with that of removing the cholesteatoma through a cortical mastoidectomy, the procedure was called *combined-approach tympanoplasty* (Jansen 1968, Smyth et al. 1967, Smyth 1969). Other names for it have been *intact canal wall tympanoplasty with mastoidectomy* (Sheehy and Patterson 1967), or just *intact canal wall tympanoplasty* (Glasscock and Miller 1976), or *intact canal wall technique* (Sheehy 1970 b), or *transmastoid tympanoplasty* (Portmann 1979). After introducing a significant modification of intact canal wall mastoidectomy, the present author introduced the term *classic intact canal wall mastoidectomy* in order to distinguish it from the various modifications (Tos 1978 a).

Evolution of Classic Intact Canal Wall Mastoidectomy

Prior to the early 1950s, the only operations performed in cases of cholesteatoma and active chronic otitis media were the radical (Figs. **22, 23**) and modified radical operations (Figs. **8, 9**), aiming to exteriorize the disease and create an open cavity. The disadvantage in these was the production of a cavity, with the necessity of lifelong postoperative care to remove the epithelial debris as well as the serious risk of recurrent discharge. An operation that has always been very popular is Bondy's operation (Figs. **10, 11**), which can only be used in attic cholesteatoma (Bondy 1910). Using this method, Bondy was able to control the disease and preserve hearing in selected cases.

Preservation of the Soft Meatal Wall

Before the tympanoplasty era, between 1920 and 1950, several methods of preservating the intact ear canal skin and achieving repneumatization of the cavity in connection with a modified radical operation, including removal of the posterior bony ear canal wall, were applied. The aim was to remove the disease and avoid a meatal flap and a cavity.

Barany (1921, 1923) performed atticoantrotomies including mastoidectomies and conservative radical operations without a meatal flap by preserving the ear canal skin intact. Dagget (1949) and Sheridan (1950) performed conservative radical operations, either preserving or removing the bony bridge, incus, and head of the malleus, but preserving the meatal skin intact in continuity with the ear drum. The following situations can be achieved (Dagget 1949):

- Preservation of ossicles and thinned-down bony bridge.
- Preservation of all ossicles, bridge removed (Fig. **255**).
- Diseased incus removed, bridge preserved.
- Diseased incus removed, bridge removed.
- Incus and malleus head removed, bridge preserved (Fig. **256**).
- Incus and malleus head removed, bridge removed.

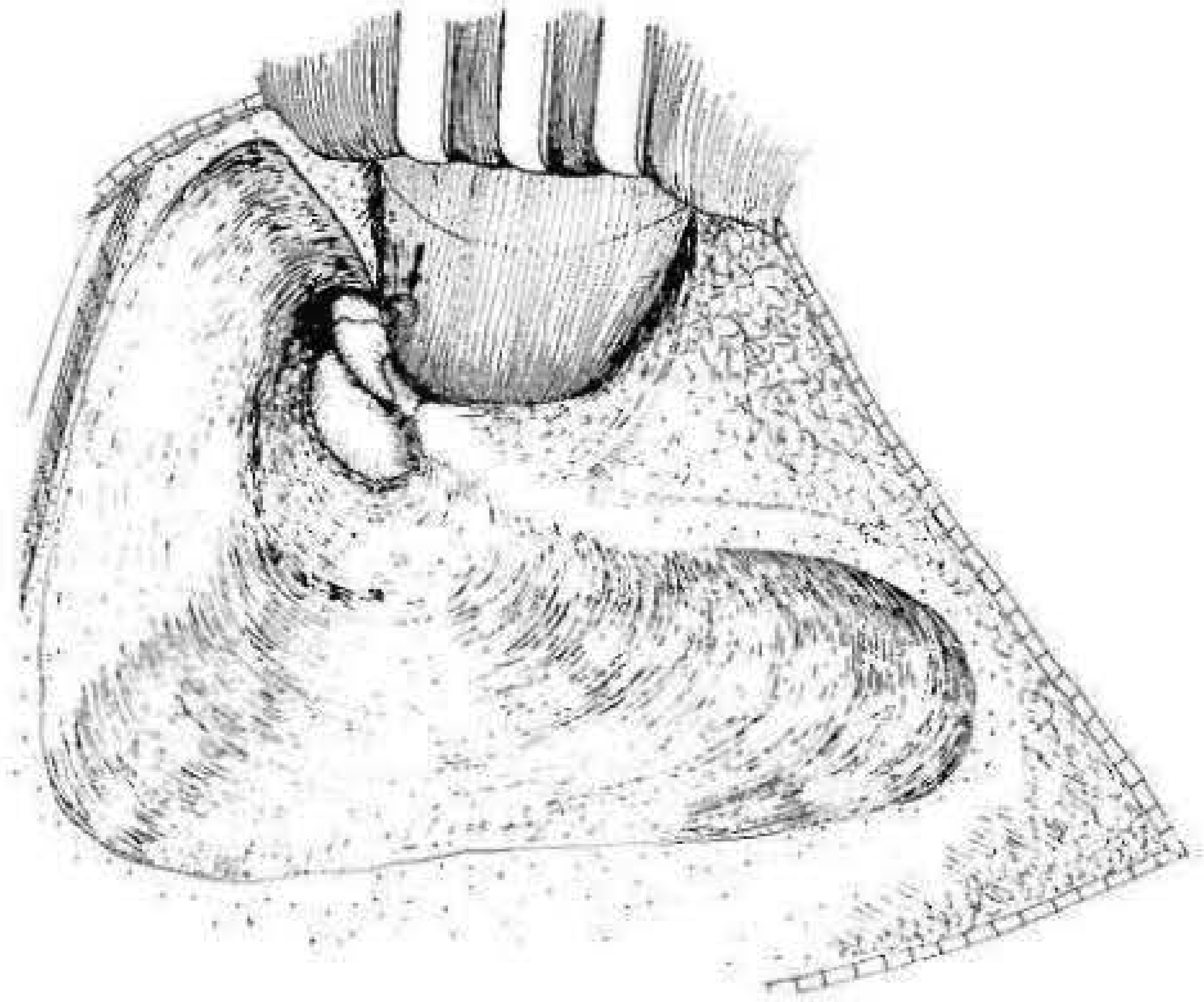


Fig. **255** **Intact soft meatal wall** (Dagget 1949) in the conservative radical operation, using a retroauricular approach with removal of the bridge but preservation of the intact soft meatal wall in continuity with the drum, in a case of an attic cholesteatoma and intact ossicular chain. The cholesteatoma membrane is removed and the neck of the cholesteatoma is pushed through Shrapnell's membrane into the ear canal (arrow) in the hope that it will grow together and close the perforation

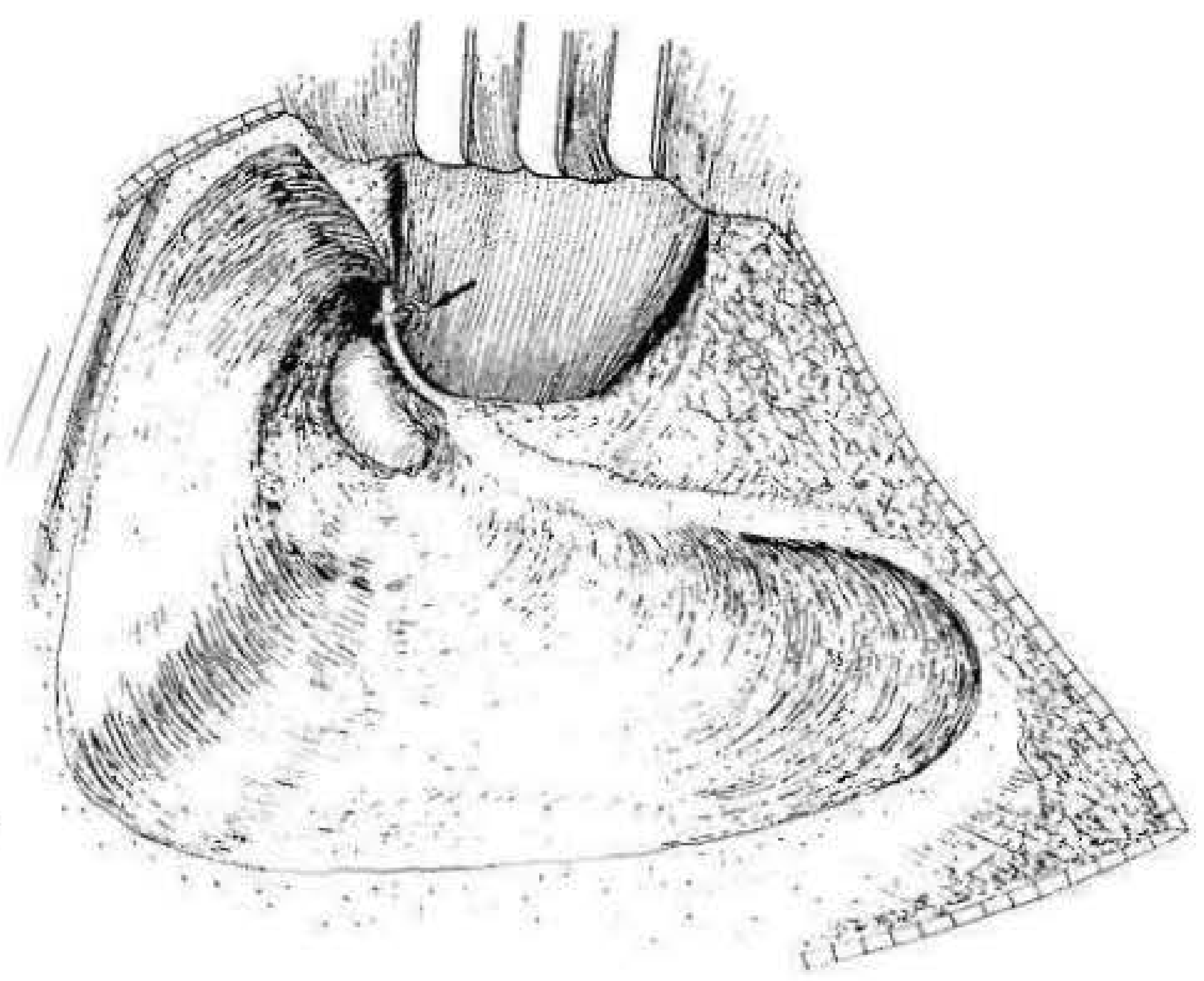


Fig. **256** **Conservative radical operation** with removal of the posterior bony ear canal wall, but with preservation of an intact bridge in a case of attic cholesteatoma. The incus is removed, the malleus head resected, and the cholesteatoma membrane removed. The neck of the cholesteatoma is pushed through the perforation into the ear canal (arrow). The soft meatal wall is intact

The intact ear canal is filled with gauze, pushing the remaining drum gently onto the medial wall of the tympanic cavity (Dagget 1949). A strip of rubber glove or oiled silk is then placed behind the drum perforation up into the attic region, temporarily closing the ear canal from the cavity (Fig. **257**). Blood is allowed to fill the cavity behind the rubber strip, which is brought out of the wound, and the postantral wound is primary closed. The rubber strip is removed after 36 hours, and the ear canal package is removed after six days. For the first ten days, the meatus appears to be somewhat narrowed, but then organization of the blood clot is followed by contraction, and the ear canal opens up as "though it was pulled back from behind." Within three months, this pulling back of the meatal soft tissue is so obvious that it is often difficult at first glance to be sure that a meatal flap was not cut and laid back into the cavity during the original operation (Dagget 1949).

These attempts to preserve the intact soft ear canal wall and to reconstruct its defect, including the drum perforation, before the tympanoplasty era, are extremely interesting, as is the obliteration of the cavity with blood clot and recognition of the retraction of the soft ear canal wall with the gradual formation of a cavity.

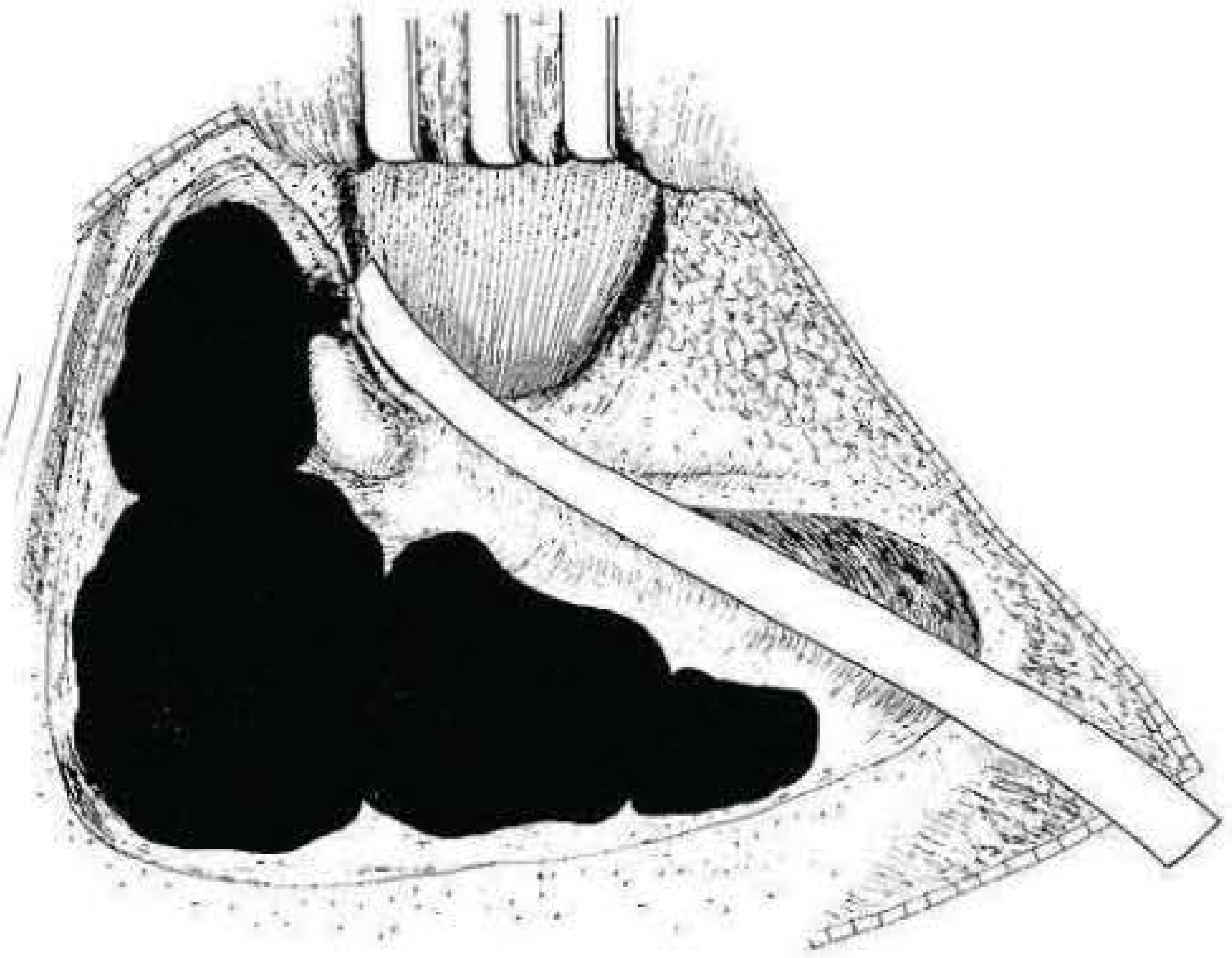


Fig. **257** After removal of the cholesteatoma, a strip of rubber glove is placed behind Shrapnell's membrane, and the cavity is filled with blood. The rubber glove strip is brought out of the wound, which is given a primary closure before the strip removed after 36 hours (Dagget 1949)

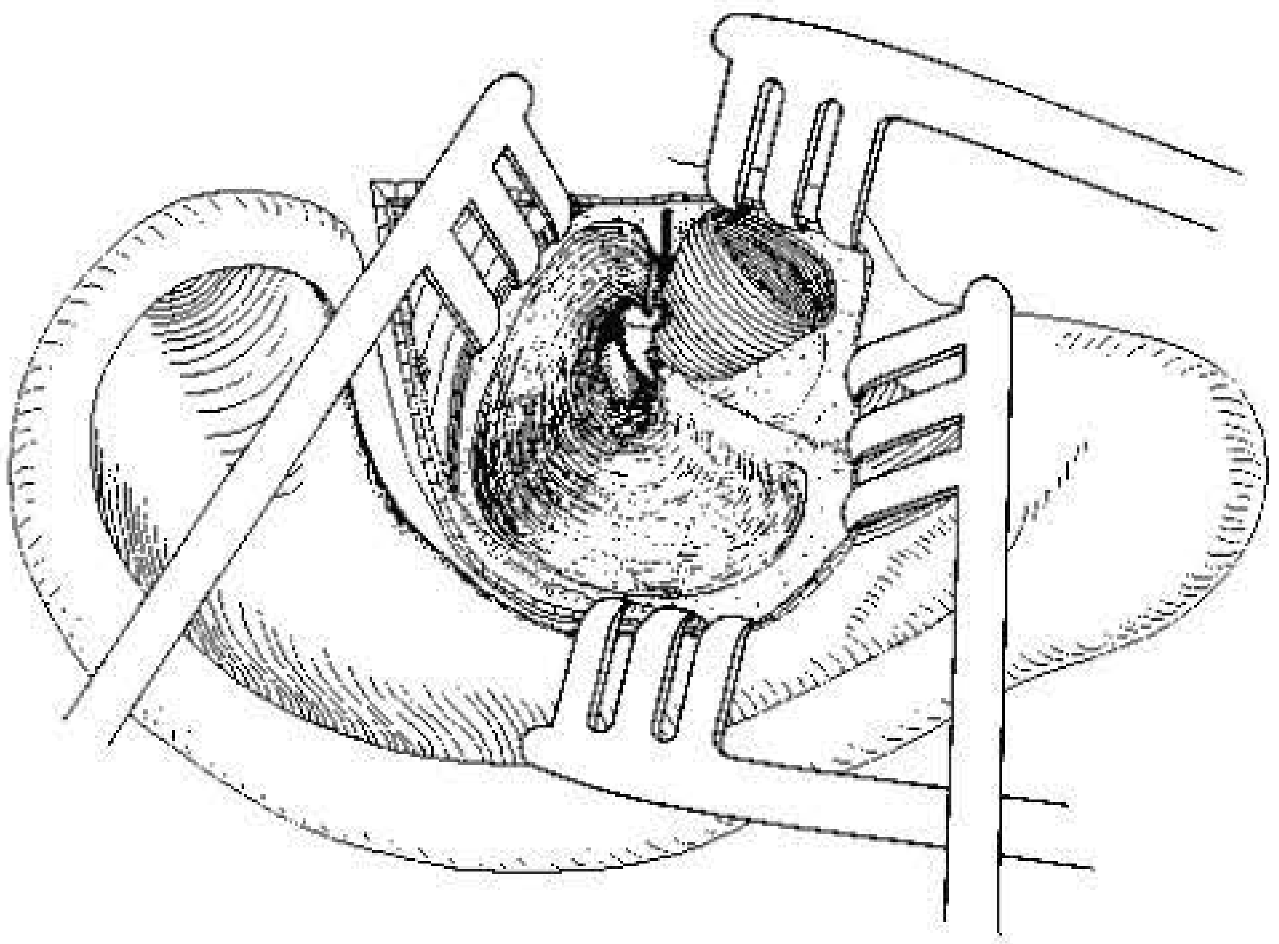


Fig. **258** **Preservation of the intact ear canal skin in the endaural approach** (Andrew 1956). An endaural conservative radical operation, with removal of the bridge and preservation of the intact ear canal skin tube. A Shambaugh incision is performed, and the lateral circular incision of the ear canal skin is continued all the way around the meatus. The ear canal skin is elevated as a tube together with the ear drum. A conservative radical operation is performed, the cholesteatoma membrane removed, and the neck of the cholesteatoma is pushed through the perforation in the Shrapnell's membrane into the ear canal (arrow).

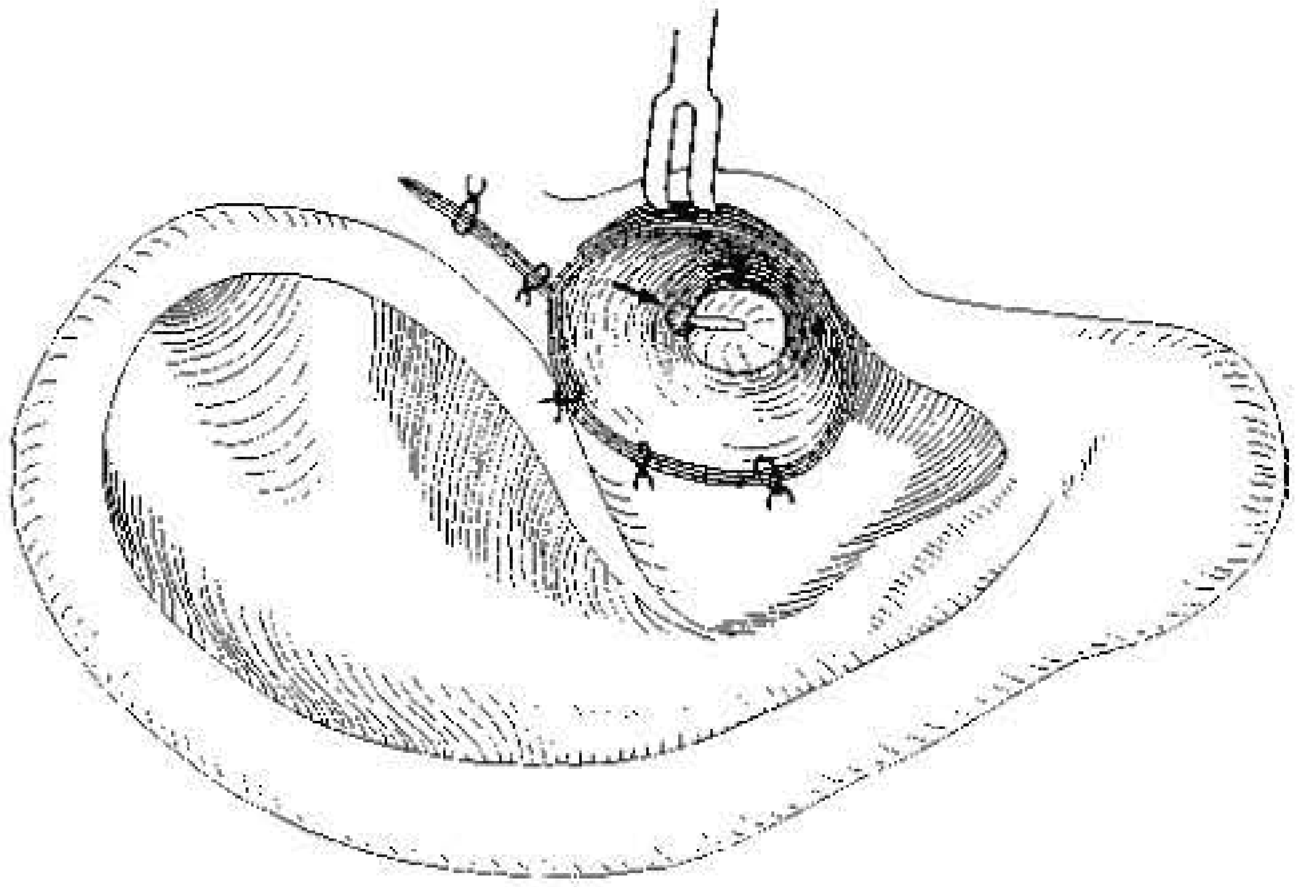


Fig. **259** After the cavity has been filled with blood, the ear canal is closed with sutures. The inverted neck of the cholesteatoma membrane is seen in the ear canal (arrow). The Shrapnell's membrane perforation is intended to close spontaneously.

Preservation of the soft ear canal was also performed in the endaural Shambaugh incision by Andrew (1956). After the Shambaugh incision (Volume 1, Figs. **50, 52**) and a lateral circumferential incision all the way around the ear canal (Fig. **258**), an endaural conservative radical operation is performed, with removal of the posterior bony ear canal and the bridge. The intact ear canal skin is carefully elevated and maintained intact. The attic cholesteatoma is debulked, and the matrix is elevated from the intact ossicular chain. The neck of the cholesteatoma at Shrapnell's membrane is inverted into the ear canal (Fig. **258**). The ear canal skin is closed with sutures, and the cavity behind the ear canal is fills with blood (Fig. **259**). The cholesteatoma perforation in the Shrapnell's membrane region is supposed to close spontaneously. Andrew selected cases with attic cholesteatoma and an intact ossicular chain for this type of operation, with preservation of good hearing. Andrew (1956) followed nine patients for more than one year, achieving good results.

During the tympanoplasty era, Pou (1960) and Collins (1964) performed an identical operation to Andrews, but the perforation was closed with a skin, vein, or fascial graft, and the possibly defective soft ear canal wall was reconstructed.

After the introduction of tympanoplasty techniques by Wullstein and Zöllner in the mid-1950s, improvement of hearing and control of cholesteatoma was possible (Wullstein 1956, Zöllner 1957, 1959). In the late 1950s, Rambo (1957) and Guilford (1960) introduced obliteration techniques to avoid a cavity and improve hearing.

Preservation of the Bony Ear Canal Wall

In 1931, Morrisset Smith published his "new radical operation," which was probably the first attempt to preserve the intact bony ear canal wall in surgery for chronic otitis media (Smith 1931). The idea was to create a mastoid cavity that would be filled with granulation tissue and a tympanic cavity, also filled with granulation tissue and covered with the ear canal epithelium. Using the retroauricular approach, a complete cortical mastoidectomy is performed, with preservation of a thin, but intact, bony ear canal wall. The posterior ear canal wall skin is then elevated and pushed anteriorly. Through the ear canal, using a combined approach, the ear drum with the fibrous annulus, and the malleus and incus are removed. All the middle ear mucosa and the Eustachian tube mucosa are removed with a curette. This is accomplished without removing the bony posterior ear canal wall (Fig. **260**) that separates the middle ear from the mastoid cavity, allowing the mastoid cavity to fill with healthy granulation tissue, as in simple mastoidectomy after acute mastoiditis. The tympanic cavity should also fill with healthy granulation tissue, and epithelialization of the granulations should take place from the ear canal skin. Smith (1931) never published any results of this operation.

An intact canal wall mastoidectomy with an enlarged ear canal was described and used by Brunar in 1957 (Brunar 1958, 1959). Through a retroauricular approach, the posterior ear canal skin is elevated, and the bony ear canal is widened by about 2 mm by transmeatal drilling of the posterior bony wall. An intact canal wall atticoantrotomy and mastoidectomy is performed, leaving an intact bony ear canal wall that is 1 mm thick and posteriorly displaced by about 2 mm, because of the initial widening of the ear canal (Fig. **261**). In this technique, Brunar used Wullstein's inspection hole through the facial recess in order to inspect the stapes. Wullstein (1956) called this lower inspection opening (Fig. **262**) "*Untere Paukenkontrolle,*" the term originally used in fenestration operations. Later, this hole was used to inspect the incudostapedial joint and the stapes in myringostapediopexy.

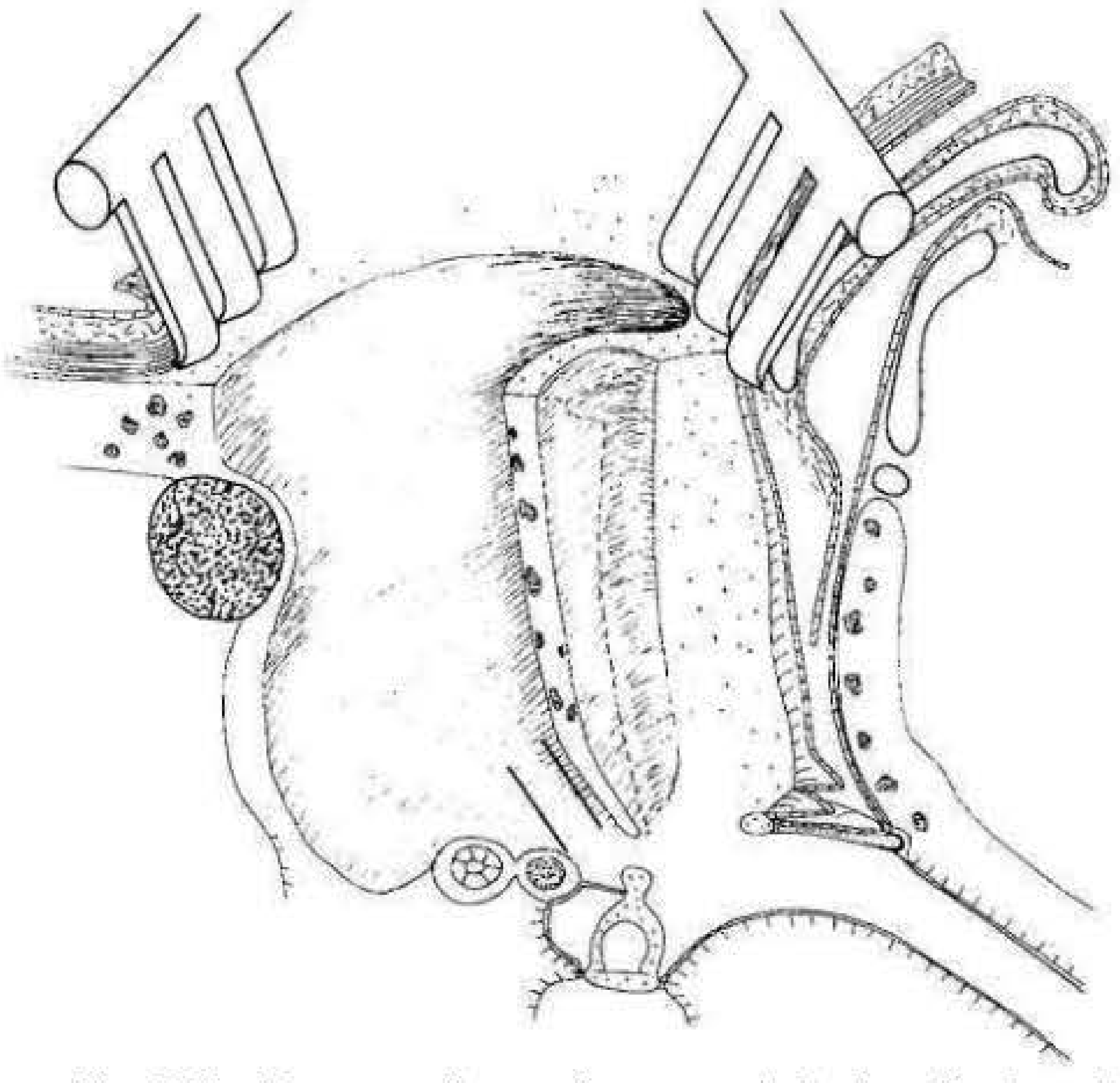


Fig. **261** **Preservation of a posteriorly displaced intact bony ear canal wall** (Brunar 1959). Perspective side view of Brunar's intact canal wall mastoidectomy. After elevation of the posterior canal wall skin, the ear canal is enlarged by intrameatal drilling for about 2 mm. The dotted line indicates the original position of the bony ear canal wall. An intact wall mastoidectomy is performed. The bony ear canal wall is thinned to 1 mm thickness. The Wullstein lower inspection opening is carried out, indicated here by the two solid lines in the facial recess.

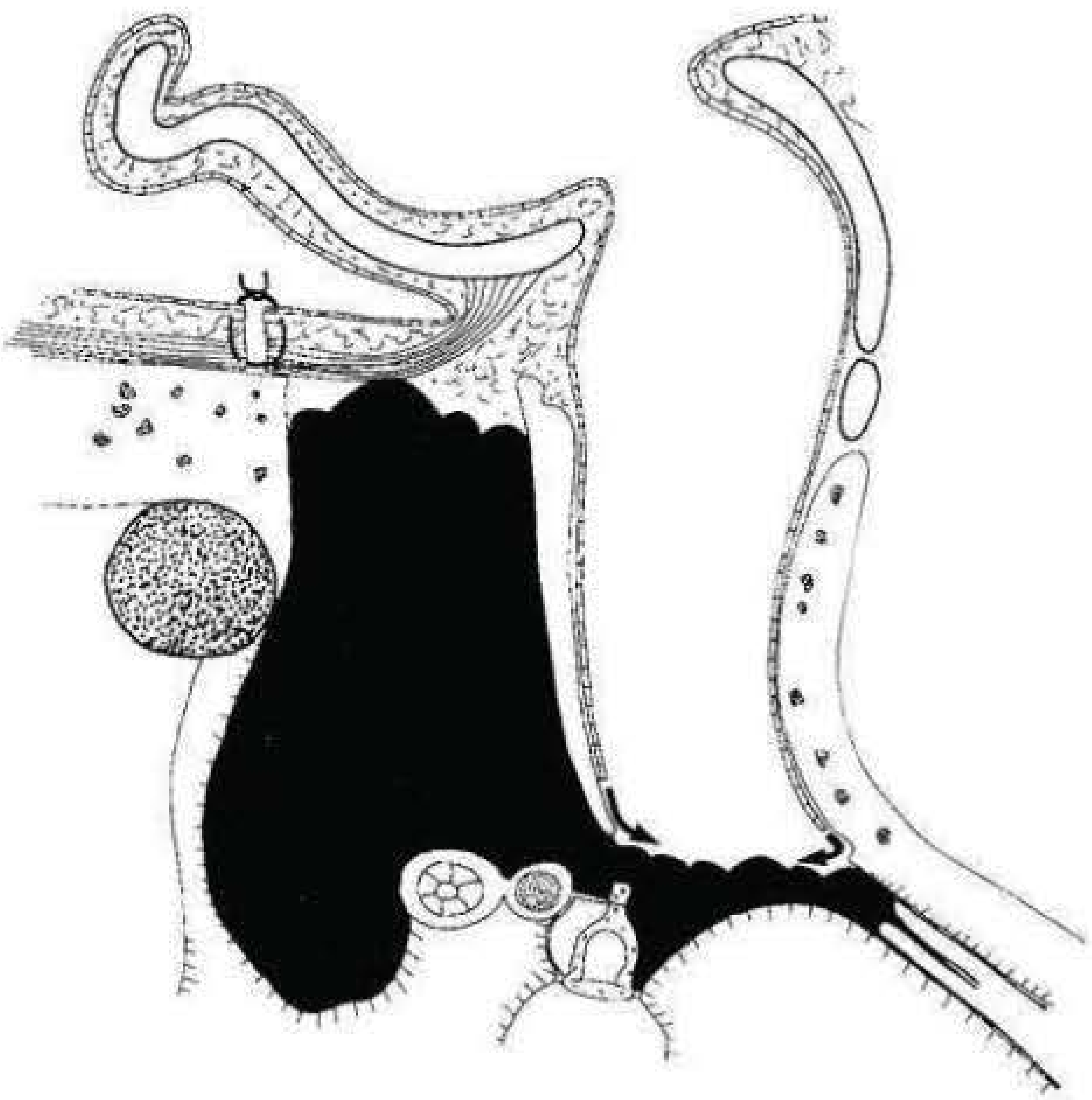


Fig. **260** **Preservation of the intact bony ear canal wall** (Smith 1931). Side view of the "new radical operation" with preservation of an intact bony ear canal wall. The ear drum and the fibrous annulus, malleus, and incus are removed. The mastoid cavity and the tympanic cavity are filled with blood, and the intention is that healthy granulation tissue should fill the mastoid cavity and the tympanic cavity. The granulation tissue in the mastoid cavity will be epithelialized from the ear canal (arrows). The Eustachian tube is intended to remain closed.

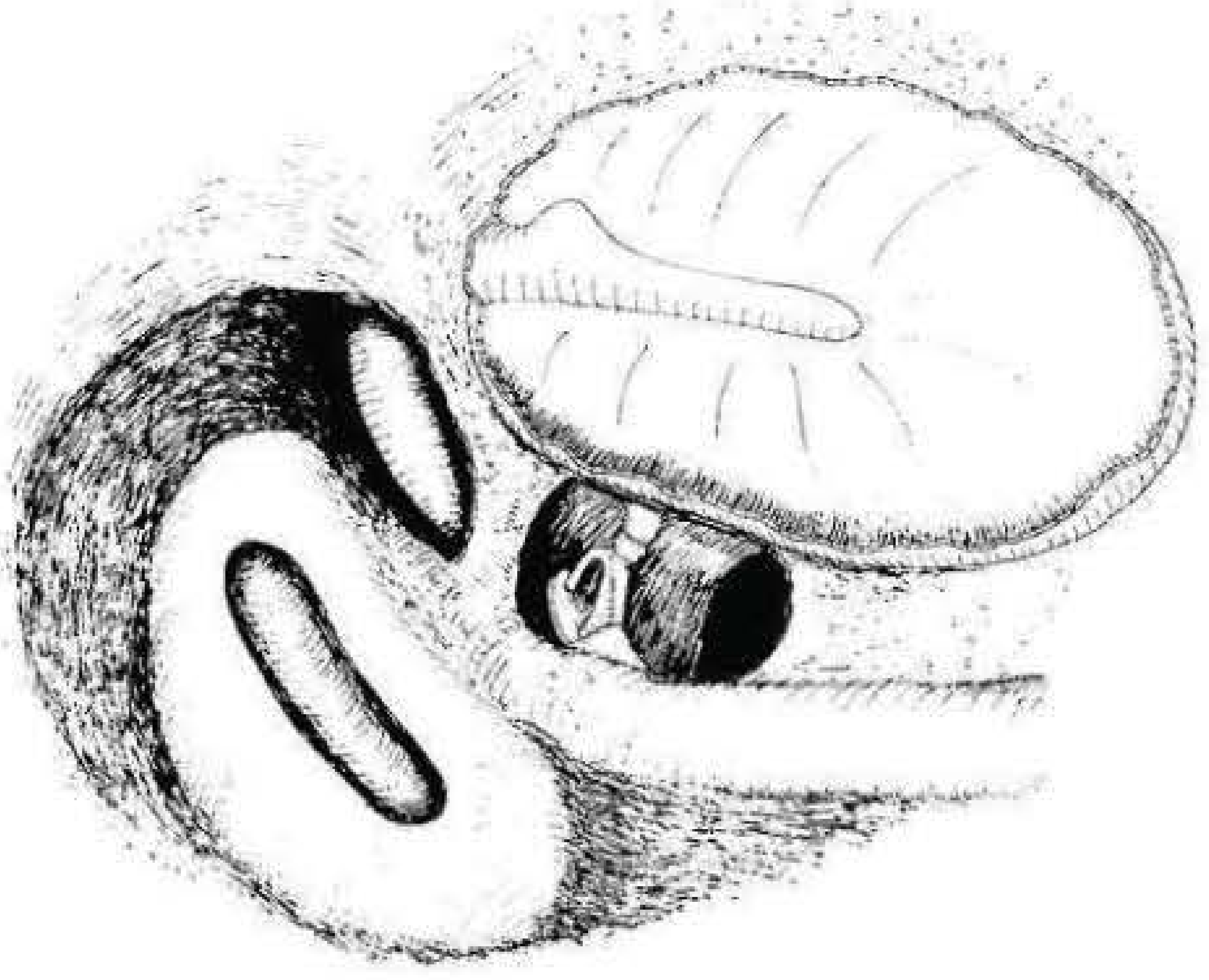


Fig. **262** **The original Wullstein lower inspection opening** through the facial recess, in a situation with fenestration of the lateral semicircular canal. The stapes and the incudostapedial joint as well as the round window, are visible through the hole. The facial nerve is skeletonized, and a broad posterior buttress has been left in place, partly hiding the inferior edge of the short process of the incus. Fenestration is performed on the lateral semicircular canal.

Brunar reconstructed the defect in the ear canal with full-thickness skin grafts, and hoped for repneumatization of the cavity.

Further Development of the Posterior Atticoantrotomy

In the facial-chorda angle, i. e., the facial recess, new surgical techniques for facial nerve decompression were developed during the 1950s (Lewis 1956, Wullstein 1958, Kettel 1959). These authors all described techniques in which the facial nerve is exposed by a simple mastoidectomy, with removal of the bone within the facial recess.

Applying the posterior atticotympanotomy, Jansen was the first, in 1957, to preserve the posterior bony ear canal wall in cholesteatoma surgery (Jansen 1958, Jansen 1962). In his first English publication, Jansen (1963) reported that, in the majority of surgical cases with chronic middle ear disease, using meticulous drilling and thinning it was possible to preserve the posterior bony ear canal wall. The thinning of its medial part around the ossicles was reported to achieve exposure of the lateral attic. To expose the posterior tympanum, Jansen elaborated and widened the original Wullstein lower inspection opening, especially towards the hypotympanum. He originally called this procedure posterior hypotympanotomy. The bone to be removed was termed by Jako (1966) the *antrum threshold.* The term *facial recess,* defining the space between the facial nerve canal and the chorda tympani, was popularized by Sheehy (1965, 1970), and this surgical term became widely accepted in the classic intact canal wall mastoidectomy technique.

In the USA, the Otological Medical Group (Los Angeles) started performing intact canal wall technique in 1958, and published their methods (House and Sheehy 1963, Sheehy 1965) and their first results (Sheehy and Patterson 1967). Myers and Schlosser (1960), Austin and Shea (1961), and Corgill and Martinez (1963) have also independently performed intact canal wall mastoidectomy operations.

During the 1960s and early 1970s, the intact canal wall mastoidectomy became a very popular method and was used in many centers, but the late results soon showed some disadvantages of the technique. There was a high percentage of residual cholesteatoma in the tympanic sinus, which could not be properly removed through the extended posterior atticotympanotomy. Also, a high frequency of residual cholesteatoma in the anterior attic was found, demonstrating that exposure of the anterior attic is often not sufficient. In addition, there was a high frequency of recurrent cholesteatoma, manifesting initially as retraction into the posterior tympanum, around the intact bony wall and into the attic and aditus ad antrum (Smyth et al. 1967, 1971, Smyth 1976). Many surgeons abandoned the intact canal wall technique and went back to canal wall–down techniques, while others performed canal wall–up mastoidectomy in two stages, thus allowing a "second-look" procedure to check that no cholesteatoma remained behind the intact ear drum or intact posterior ear canal wall.

Surgical Technique

Incision

Any retroauricular skin incision can be used, and these are described in Volume 1, Chapter 4. The retroauricular fold incision or posterosuperior incision (Portmann 1979) (Volume 1, Figs. **123, 124**) is placed at the most anterior point in the postauricular fold. If these incisions are used, then the subcutis–periosteum incision is placed along the entrance of the bony ear canal; but then an additional subcutis–periosteum incision has to be performed along the lower edge of the temporalis muscle. The subcutis and periosteum are elevated and held with selfretaining retractors. In Portmann's (1979) skin incision, as well as the subcutis–periosteum incision around the entire bony canal entrance, two additional, posteriorly directed incisions are performed, one superiorly and one inferiorly, allowing further elevation of a posterior-based flap (Volume 1, Fig. **32**), thus exposing the cortex of the mastoid process.

Using the retroauricular flap incision 1–5 cm behind the retroauricular fold (Volume 1, pp. 55–59), the subcutis–periosteum incision is performed at the same level as the skin incision, and the flap is elevated anteriorly, including either subcutaneous tissue and periosteum together with the skin, or separately, creating an anteriorly-based subcutis–muscle–periosteum flap. This flap can be useful in obliteration and reconstruction of the ear canal if it becomes clear that a canal wall–up procedure cannot be performed. The present author therefore prefers the retroauricular flap incision, with creation of an anteriorly based subcutis–muscle–periosteum flap.

Ear Canal Skin Elevation

The goals of ear canal skin elevation are to expose only as much bone as necessary, to preserve all attached skin as intact flaps, and to protect the flaps during the surgery. This can be achieved in several ways, as described in Volume 1, Chapter 4, i. e., performing a medially-placed circumferential incision between the 12-o'clock and 6-o'clock positions, and two radial incisions at the 12-o'clock and 6-o'clock positions, running laterally. In this way, a large laterally based skin flap is pushed anteriorly toward the anterior wall, and held in place and protected with a special House–Sheehy retractor (Volume 1, Fig. **107**). The circumferential incision can be placed more laterally in the ear canal, with the result that the medial tympanomeatal flap is larger and the lateral flap shorter. The lateral flap can be turned posteriorly outward, retracted, and held in place with a protective selfretaining retractor (Fig. **263**) or a strip of gauze (Portmann 1979) (Volume 1, Figs. **130, 131**).

Sheehy (1970 b) used his own "posterior vascular strip technique" (Volume 1, Figs. **148–157**), with elevation and removal of the ear canal skin together with the drum remnant epithelium (Volume 1, Figs. **148–156**). The elevated posterior canal skin (the vascular strip) is turned outward and held in place with a protecting retractor.

The posterior canal skin flap can be turned around the posterior surface of the auricle and fixed there with a surgical stay (Volume 1, Fig. **155**).

The present author does not feel that ear canal skin removal is necessary, except in a few cases with very pronounced protrusion of the anterior ear canal wall.

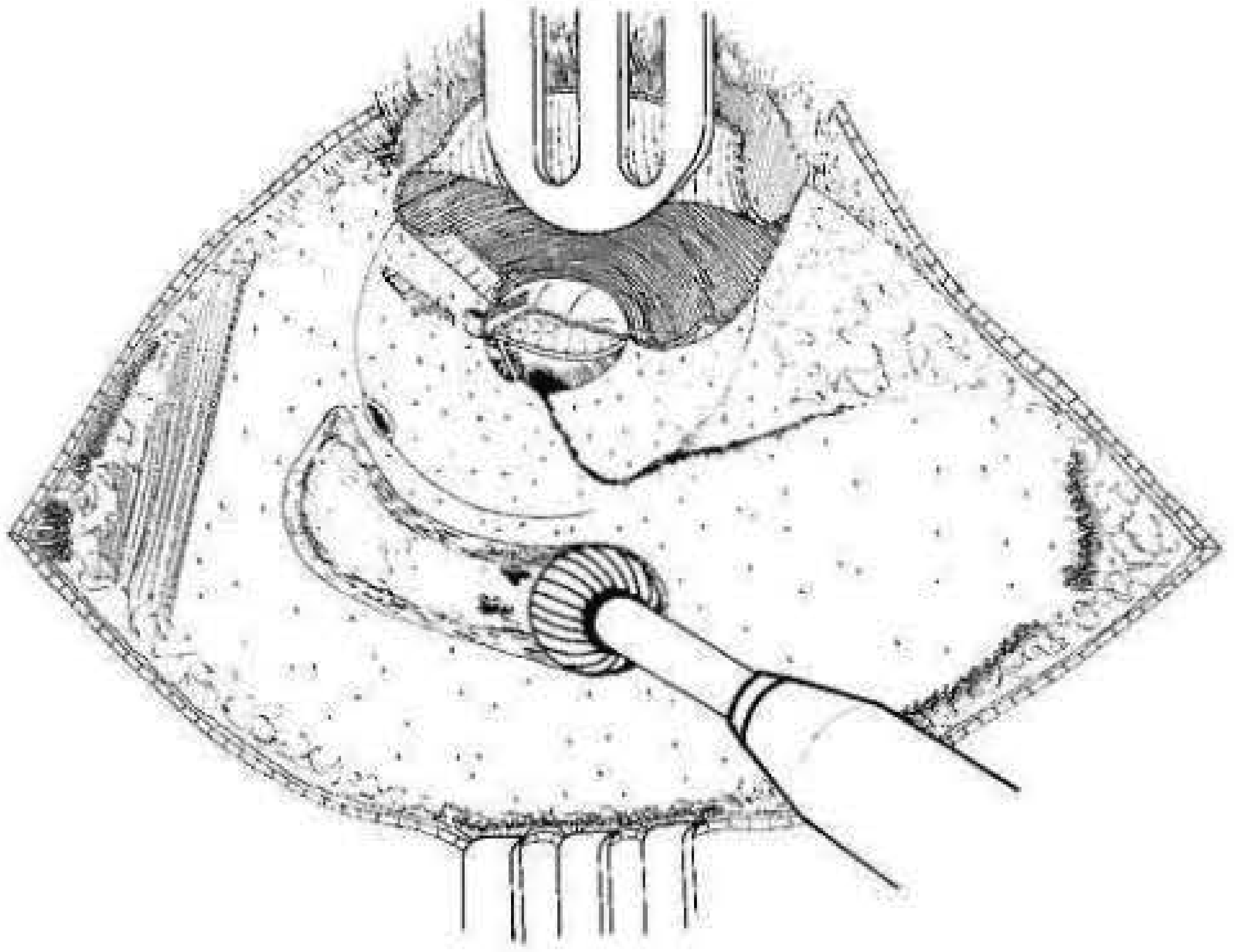


Fig. **263** **Intact canal wall mastoidectomy.** After the retroauricular incision and elevation of a subcutis–periosteum flap, a lateral circumferential canal skin incision and two radial skin incisions, at the 12-o'clock and 6-o'clock positions are performed. The posterior ear canal skin flap is elevated outward and protected by a selfretaining retractor. A large area of the mastoid cortex is exposed, up to the temporalis muscle. Drilling is started with a large cutting burr, initially making a groove along the posterior edge of the bony ear canal

Mastoidectomy

The principles of mastoidectomy are basically the same as those described in Chapter 4, but in the intact canal wall technique, attention is focused from the very beginning on thinning the posterior ear canal wall. In the present Chapter, therefore, the work around the ear canal is described in detail; the other phases of mastoidectomy are described in Chapter 4.

After exposure of the entire mastoid plane, drilling commences behind the posterior edge of the ear canal, using a large cutting burr (Fig. **263**). Drilling of the cortical bone is continued along the terminal line (Fig. **264**). Bone removal and exenteration of the air cells is gradually extended in an inferior and medial direction toward Körner's septum, depending on the pneumatization and pathology of the mastoid process (Fig. **265**).

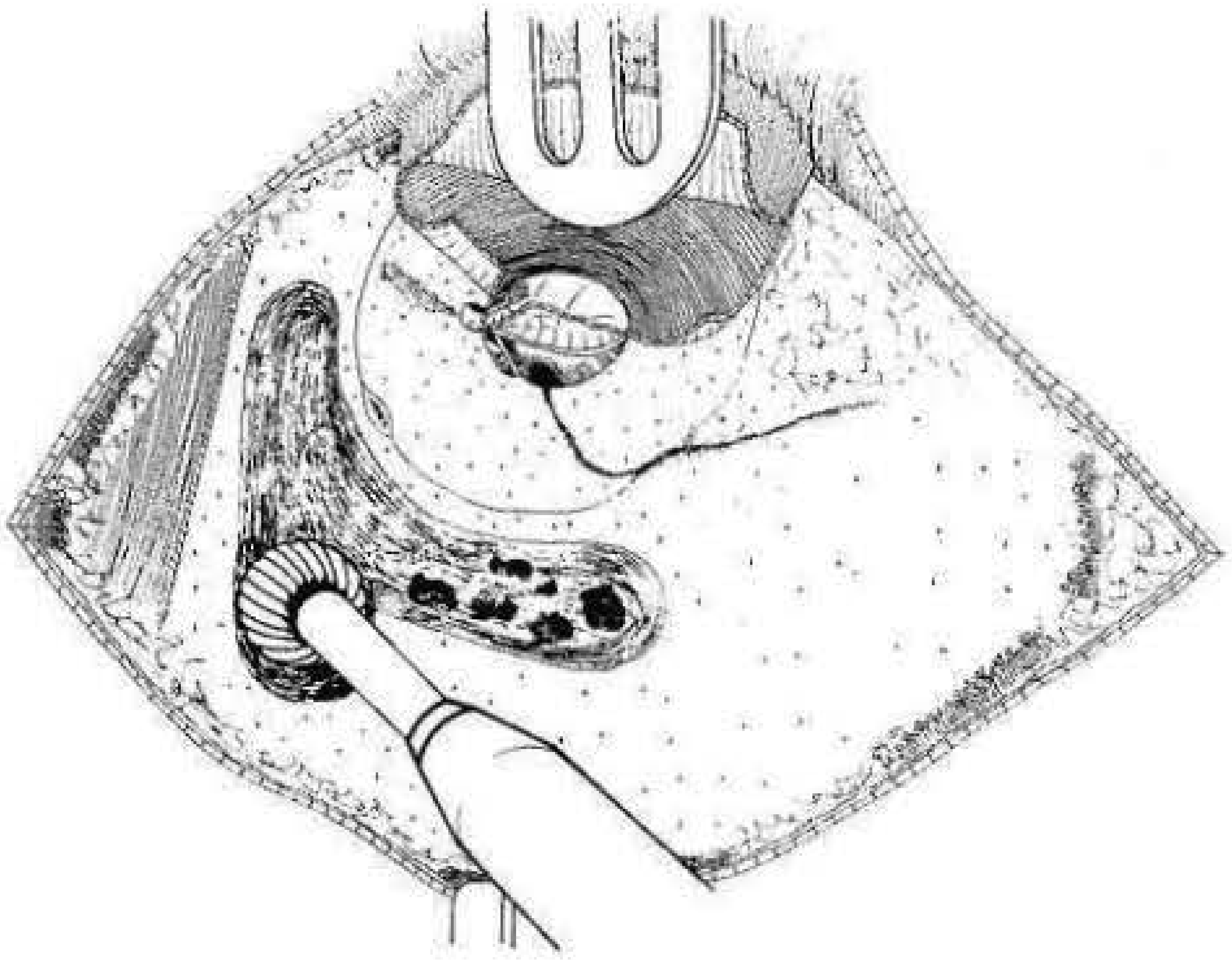


Fig. **264** The drilling is continued along the middle fossa dura plate, and the mastoid cortex is gradually removed

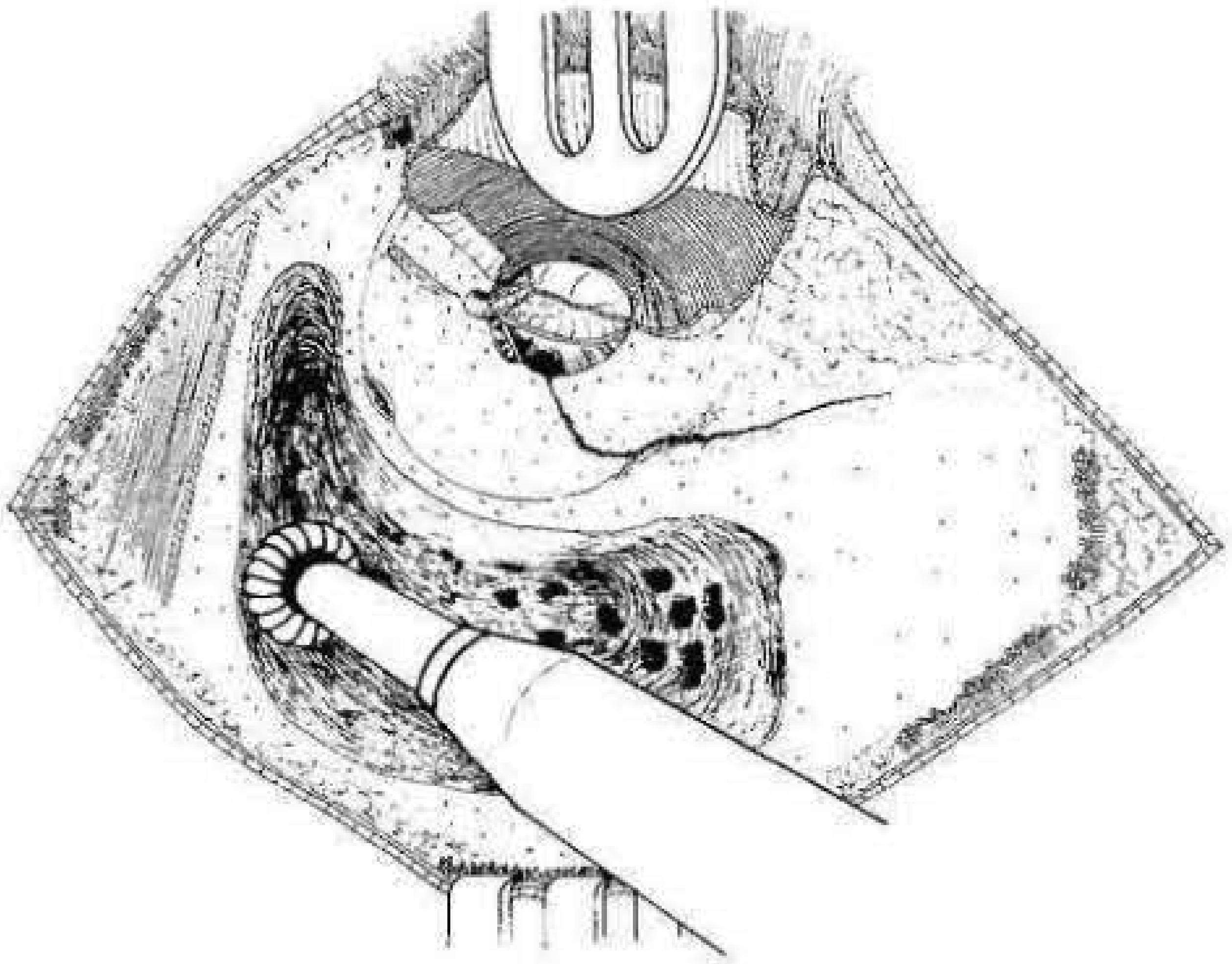


Fig. **265** The cavity is enlarged along the middle fossa dura plate, and the sigmoid sinus and lateral mastoid air cells are exenterated

Thinning the Posterior Ear Canal Wall

After exenterating the lateral mastoid air cells down to Körner's septum, the posterior ear canal wall is thinned. The patient is tilted away from the surgeon, allowing better visualization of the posterior side of the ear canal wall, which is gradually thinned with a cutting burr (Fig. **266**).

The cavity is enlarged, the sigmoid sinus is skeletonized, and the antrum is entered after removal of Körner's septum (Fig. **267**) (as illustrated in Chapter 4, Figs. **189–192**). The posterior ear canal wall is still too thick for the incus body and the prominence of the lateral semicircular canal anteromedially in the antrum to be identified, and the posterior ear canal wall is therefore further thinned (Fig. **268**). The thinning of the ear canal is continued until the prominence of the lateral semicircular canal becomes visible (Figs. **269, 270a**). Further drilling of the lateral

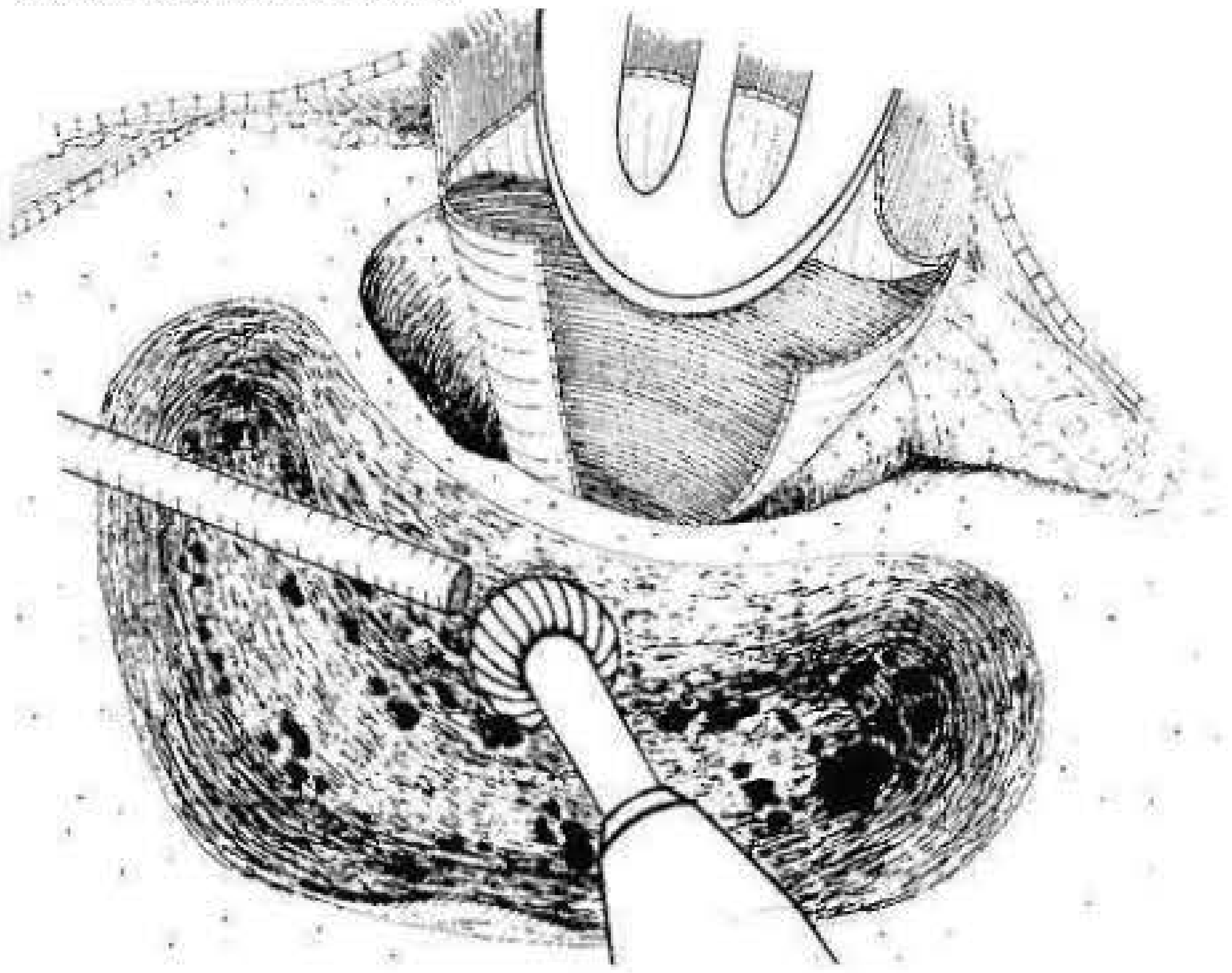


Fig. **266** The posterior side of the ear canal is thinned with a cutting burr. Körner's septum has not yet been opened

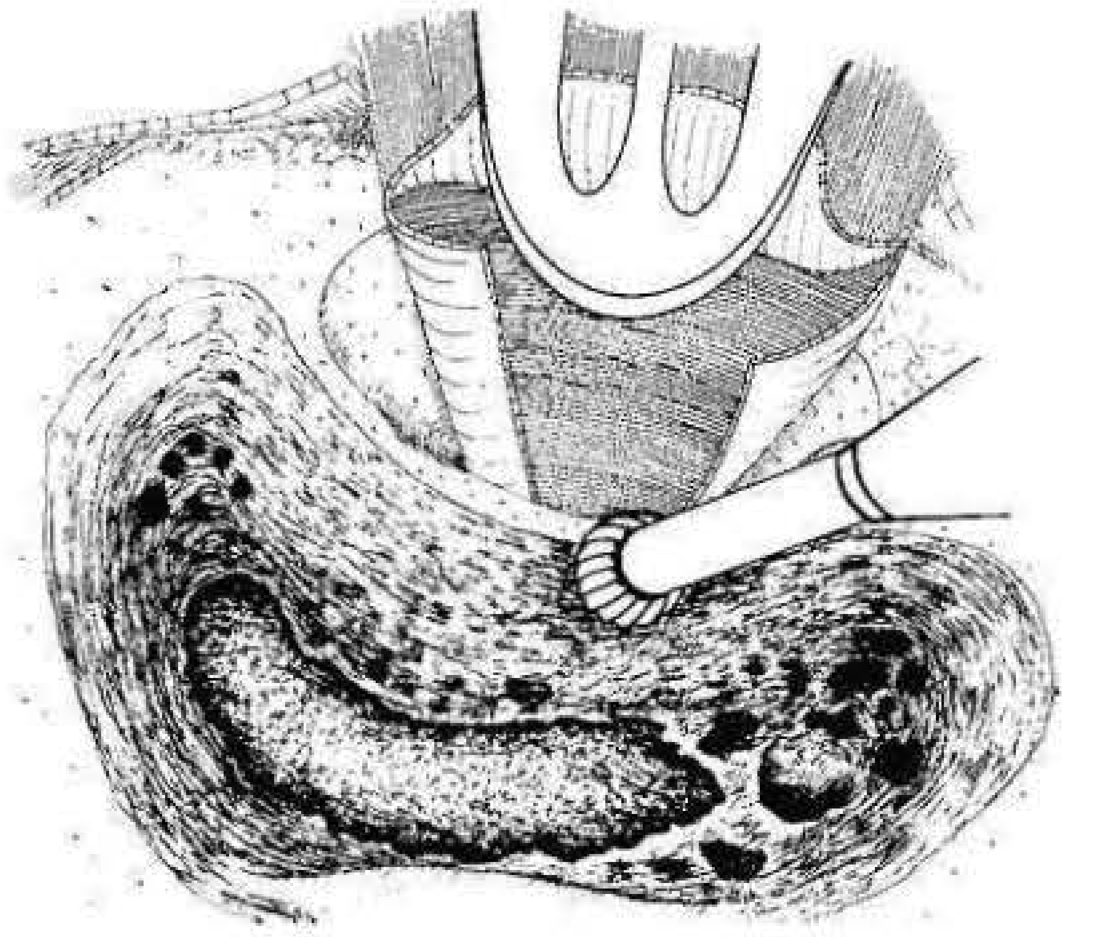


Fig. **267** Körner's septum has been removed and the antrum has been opened, as has the aditus ad antrum. Posteriorly, the cavity is enlarged and the sigmoid sinus skeletonized

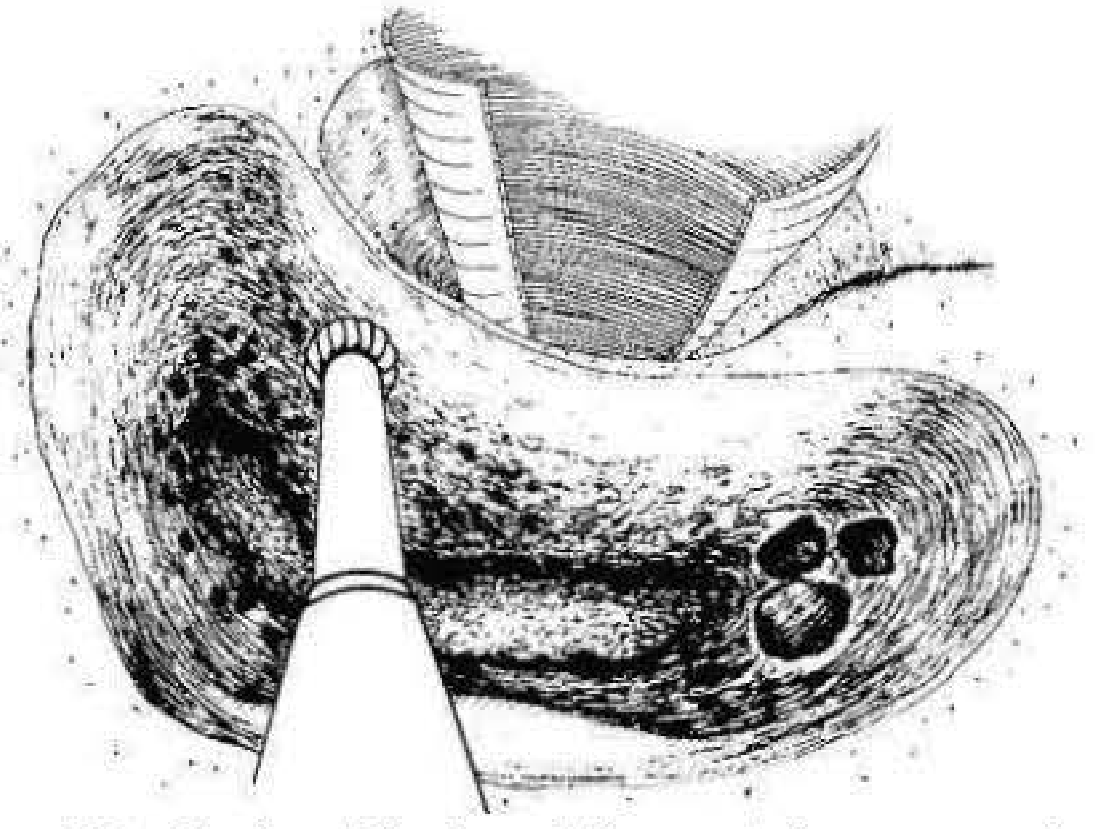


Fig. **268** Further thinning of the posterior ear canal wal is taking place

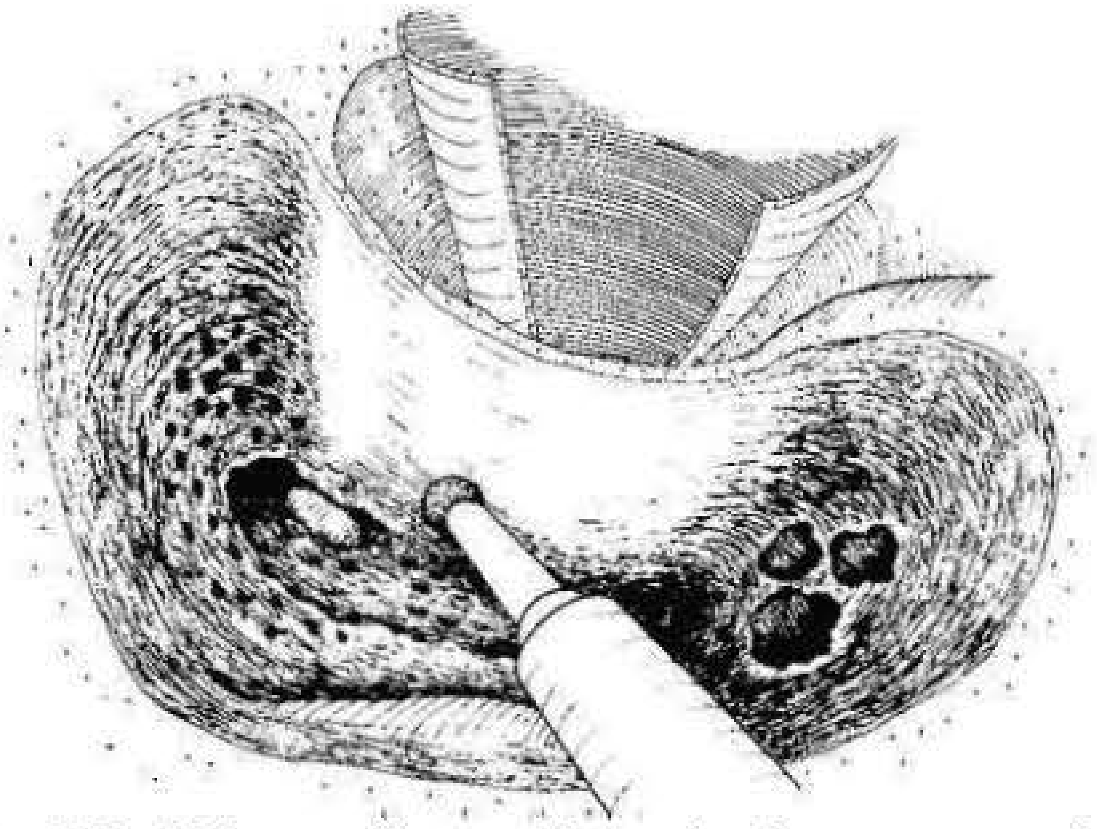


Fig. **269** Using a diamond burr, the inner ear canal is thinned medially, exposing the lateral semicircular canal. The malleus head and incus body are still covered with a bony overhang

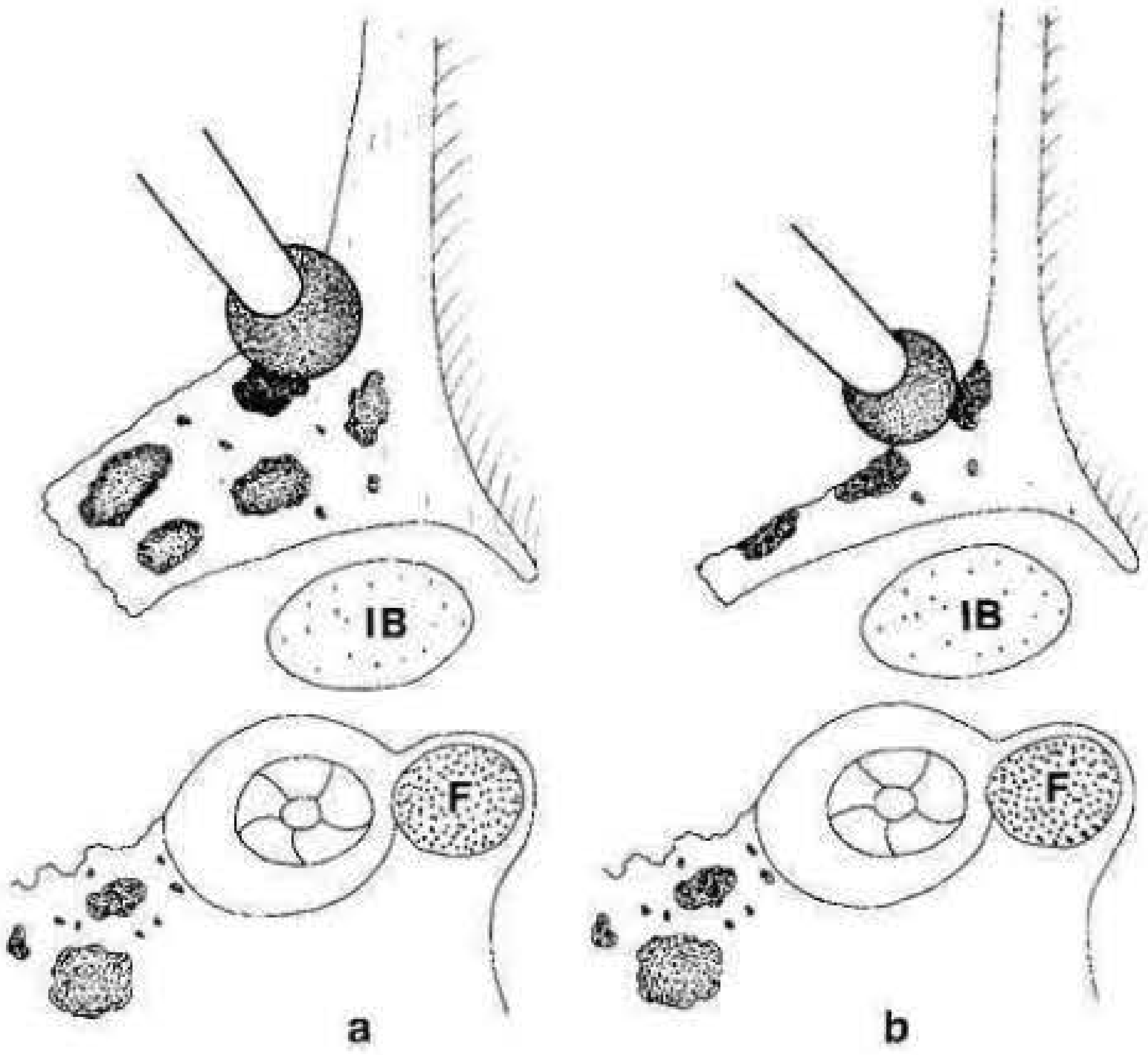


Fig. **270** **Side view of the posterior ear canal wall** with its bony overhang. F: facial nerve.
a There is still a thick bony overhang covering the incus body (IB) and part of the lateral semicircular canal.
b The bony ear canal wall is maximally thinned, as is the bony overhang covering the incus body

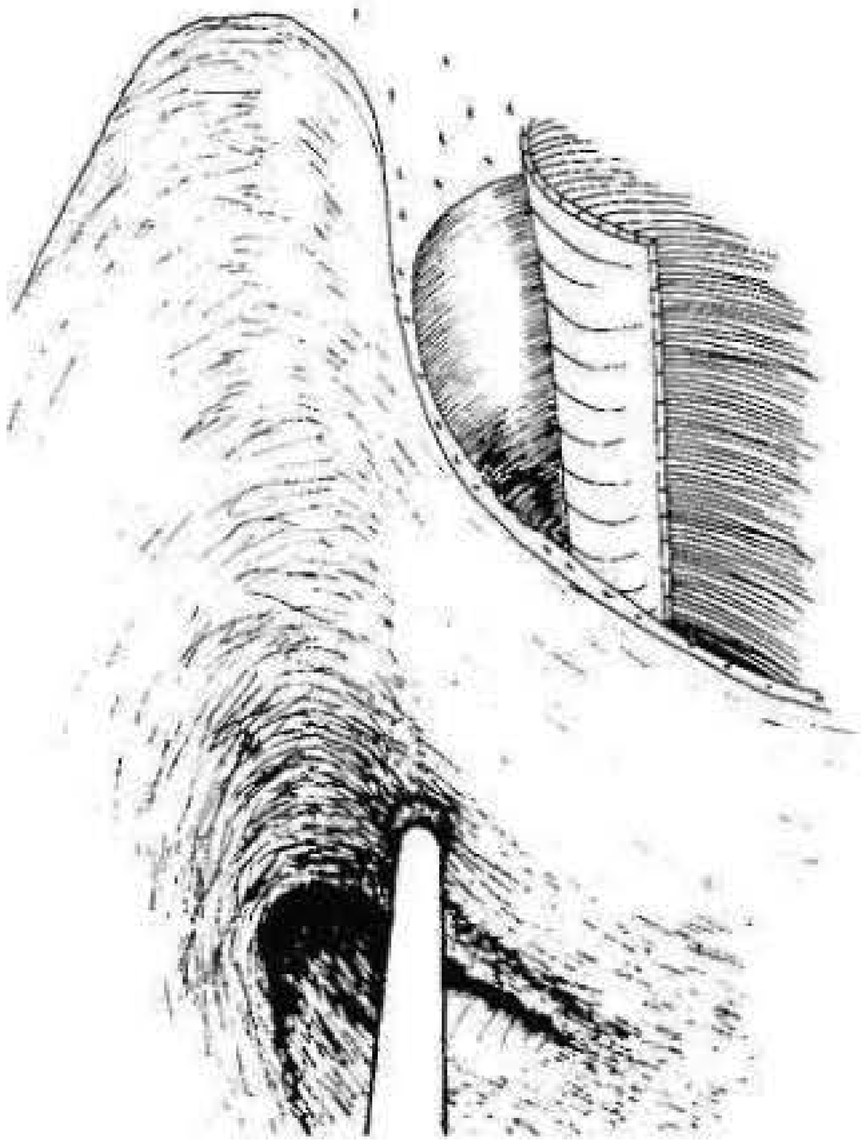


Fig. **271** Further drilling of the bony overhang covering the malleus head

attic wall and thinning of the ear canal exposes more of the lateral semicircular canal, but the incus body is still not visible (Figs. **271, 270b**).

Lateral Atticotympanotomy

Further careful drilling with a small diamond burr and further thinning of the ear canal is required to expose the lateral aspect of the incus body (Fig. **272**). This procedure has been called *superior tympanotomy* (Smyth 1980); the present author prefers the term *lateral atticotympanotomy,* which is more precise, firstly to avoid confusion with a similar term for elevation of the superior tympanomeatal flap, earlier called *superior tympanotomy* by Wullstein (1968). The procedure itself involves the thinning of the lateral attic wall in order to enter the tympanic cavity through the lateral attic, so that it is best described as lateral atticotympanotomy. The last overhang of the lateral attic wall covering the incus body can be carefully fractured out using a House curette (Fig. **273a**). Finally, the posterior and lateral aspects of the malleus and incus body become visible (Figs. **273b**, and **274**).

To complete the lateral atticotympanotomy, some drilling of the lateral attic wall is required in order to make it thinner so as to survey the lateral attic and enter the tympanic cavity through it. This is performed using a small diamond burr (Figs. **275**, **276**). Finally, the ear canal is maximally thinned, the lateral attic is exposed (Fig. **277**), and the instruments can pass into the tympanic cavity (Fig. **276b**). The lateral atticotympanotomy is thus complete. The thinning of the posterior ear canal has to be performed carefully, without perforation of the attic wall. If an intact ossicular chain is found, care must be taken to avoid touching the incus body and the

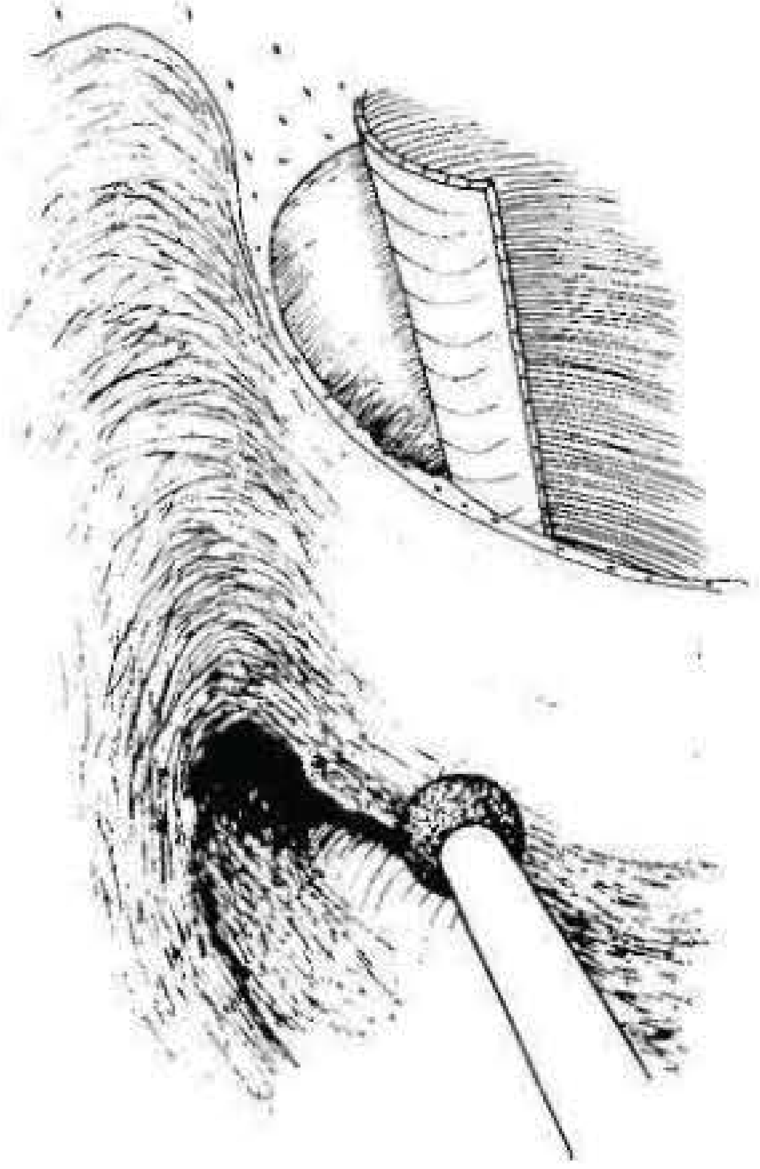


Fig. **272** **Lateral atticotympanotomy,** defined as drilling of the lateral attic wall and the bony overhang covering the incus body

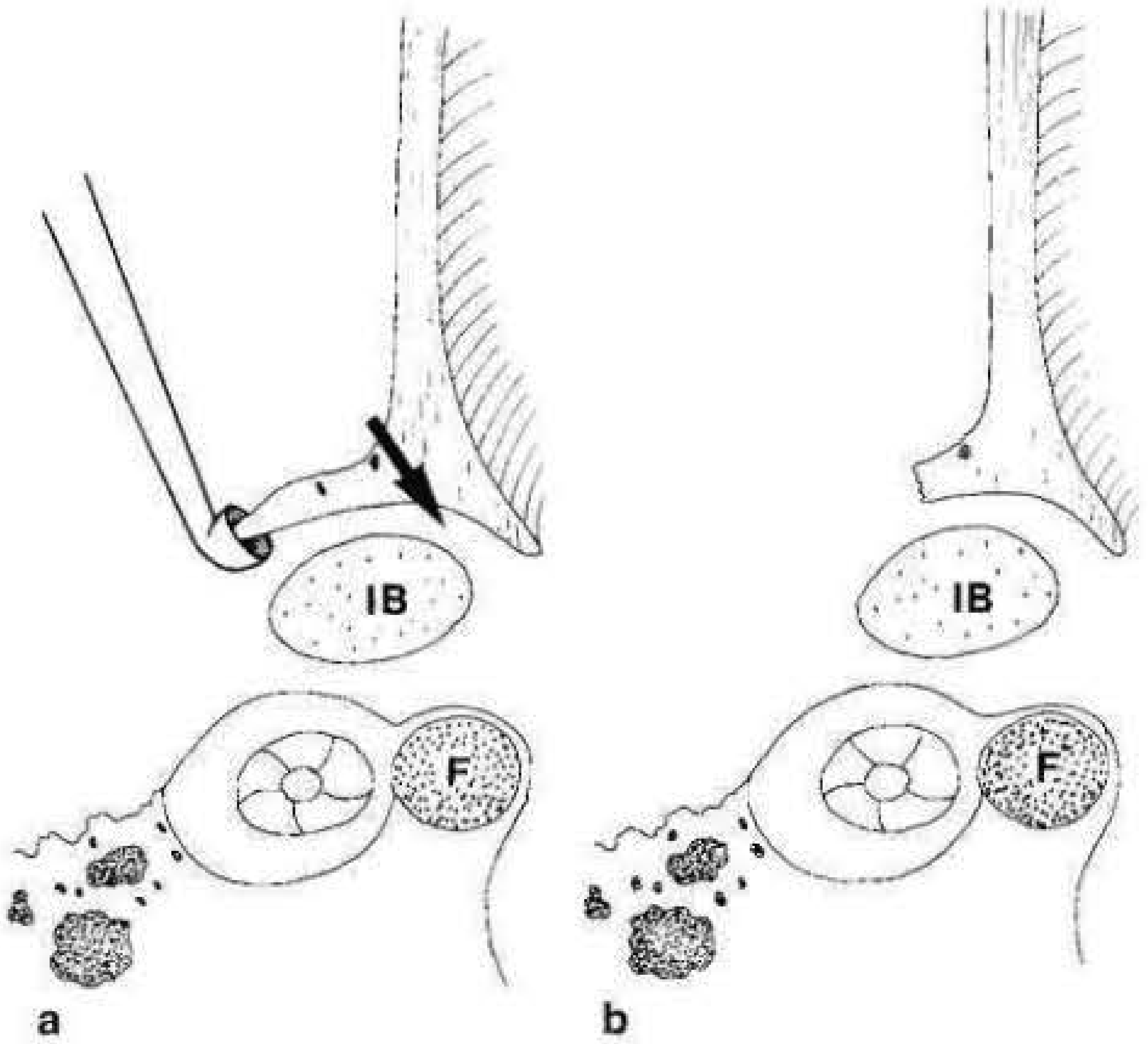


Fig. **273** **The lateral atticotympanotomy seen in a side** view, with the thinned ear canal wall and the bony overhang blocking the view of the incus. F: facial nerve; IB: incus body.

a The direction of drilling is shown by the arrow. The overhang is removed with a curette.

b There is still a small overhang covering the incus

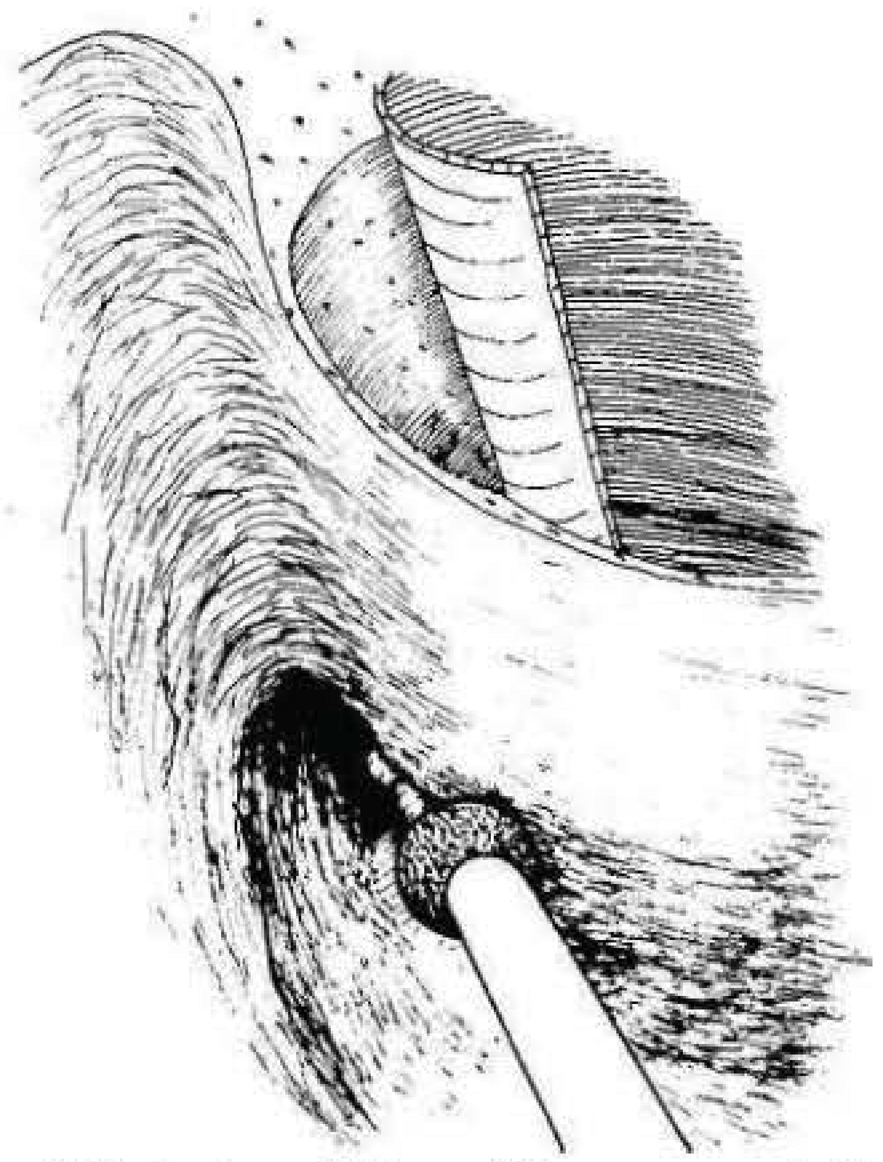


Fig. **274** With further drilling of the ear canal, the incus body and the malleus head are further exposed

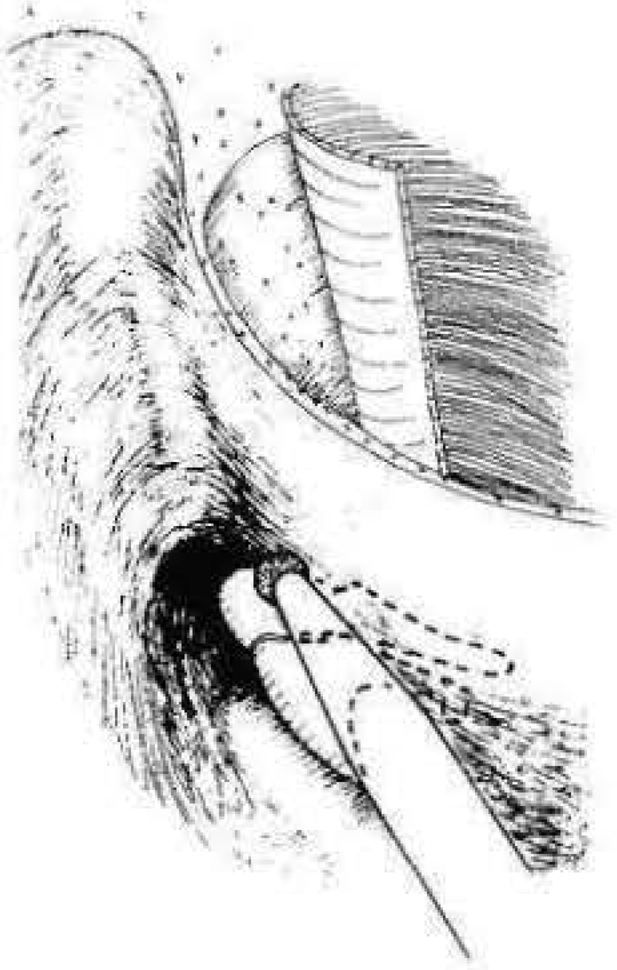


Fig. **275** Careful drilling of the bone with a small diamond burr, resulting in extreme thinning of the lateral attic wall, completing the lateral atticotympanotomy

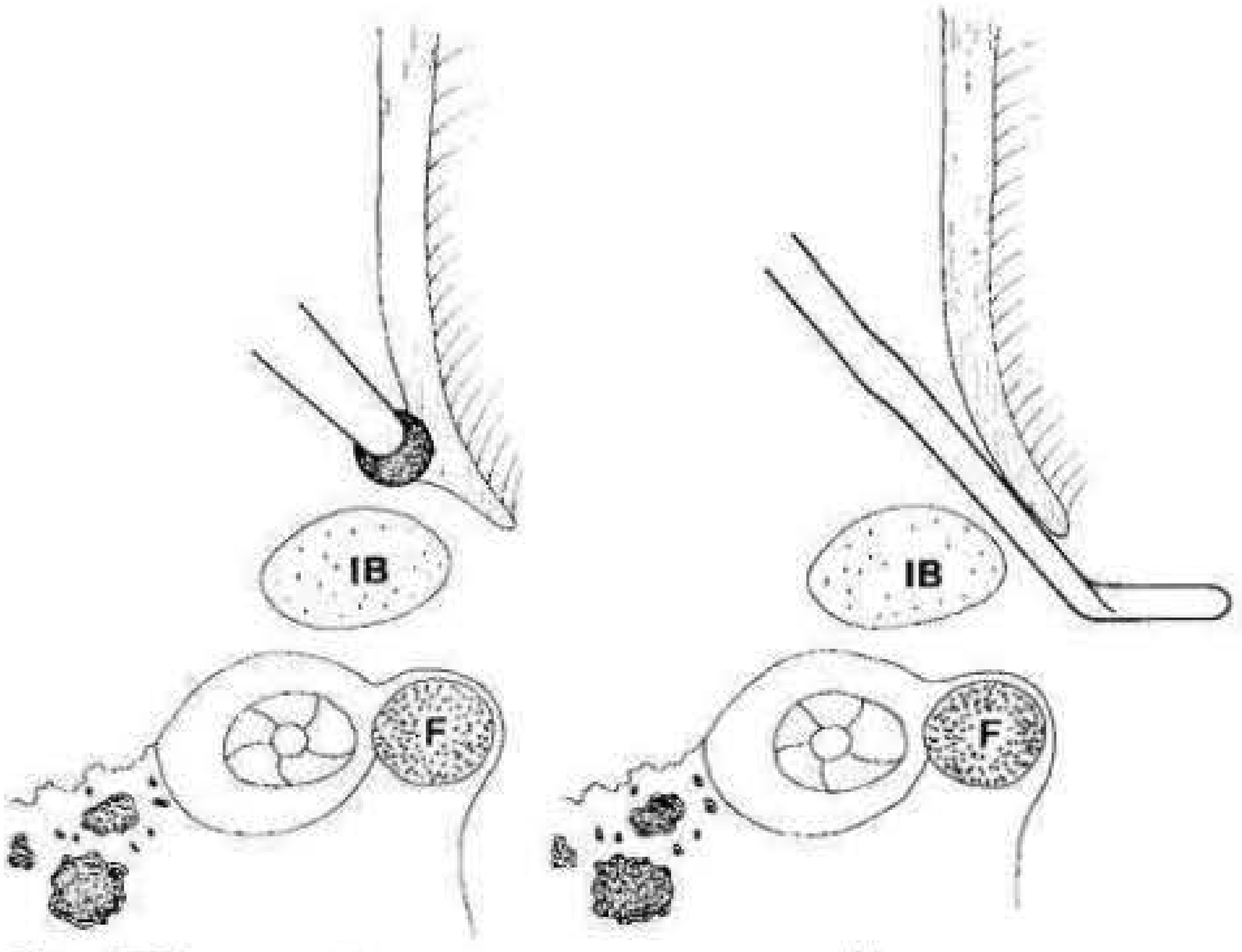
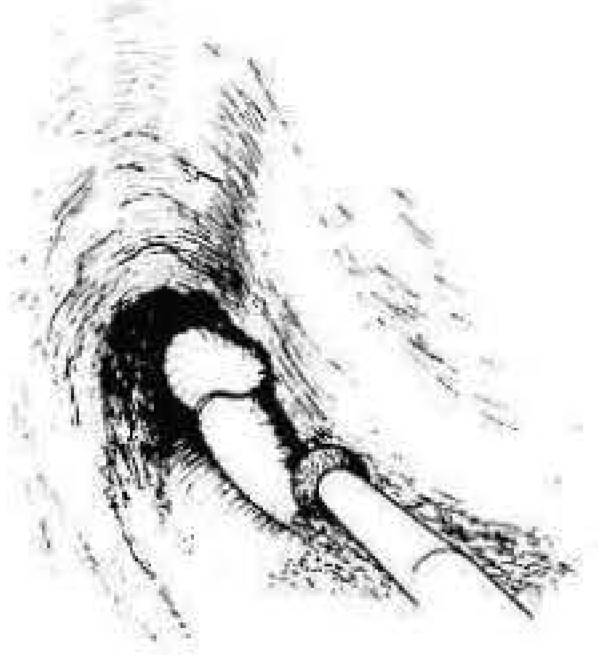


Fig. **276**

Fig. **276** **Side view of the lateral attic wall.** F: facial nerve; IB: incus body.

a The last overhang of the lateral attic wall is drilled away with a diamond burr.

b A good communication is produced between the lateral attic and the tympanic cavity by extreme thinning of the lateral wall



◁ Fig. **277** Final thinning of the posterior aspect of the lateral attic wall and the posterior buttress, defined as the bony connection between the posterior ear canal wall and the lateral semicircular canal at the level of the incudal fossa malleus head with the burr. Thinning is therefore a difficult procedure, and requires much practice on temporal bones. Thinning of the ear canal wall has to be extended to the anterior attic and the posterior attic along the short process of the incus, at which point a small bony bridge between the ear canal wall and the horizontal semicircular canal—the posterior buttress—is left intact. Inferior to the buttress, the posterior atticotympanotomy is performed.

Posterior Atticotympanotomy

The author prefers the term *atticotympanotomy* instead of Jansen's term *posterior tympanotomy,* since this avoids confusion with posterior tympanotomy when referring to elevation of a posterior tympanomeatal flap. The term *posterior (transmastoid) atticotympanotomy,* already used by Farrior (1968, 1969), is also more logical, since the procedure describes the establishment of a connection between the posterior attic and the posterior tympanum. Farrior (1968) uses a similar term, *anterior atticotympanotomy,* to describe the procedure in intact canal wall mastoidectomy of connecting the anterior attic with the anterior tympanum, including the tympanic orifice of the Eustachian tube.

The drilling technique in posterior atticotympanotomy can be performed along two routes: 1) the lateral route, with initial thinning of the bony ear canal wall lateroinferior to the buttress and the short process of the incus (Fig. **278**); and 2) the medial route, with initial drilling of the bone medial to the incudal fossa at the same level as the lateral semicircular canal. In this way, the facial recess is approached medially close to the facial nerve (Fig. **278**).

Morimitsu (1991) distinguished between two types of posterior atticotympanotomy: the classic posterior tympanotomy with drilling lateral to the incus, corresponding to the lateral route and the "posterior" posterior tympanotomy, with drilling posterior to the incus corresponding to the medial route.

1. **The lateral route.** This is safer with regard to the facial nerve, and the drilling is in fact a continuation of the thinning of the bony ear canal wall (Fig. **279**), already performed in the *lateral attic wall* By drilling laterally in the facial recess just inferior to the incudal fossa, no damage to the chorda will occur, because the chorda at this level is located outside the chordal canal, and runs from the chordal canal toward the long process of the incus (Fig. **280a**). By continued thinning of the ear canal in the same direction, an opening to the posterior tympanum lateral to the pyramidal eminence is achieved (Fig. **280b**), providing a view of the lateral part of the stapes and its tendon (Fig. **281**). With further inferior extension of the drilling at the level of the chordal eminence, the chorda tympani is exposed, demarcating the lateral limit of the facial recess (Fig. **282**). With further drilling toward the hypotympanum along the course of the chorda tympani, the inferior part of the facial recess is opened (Fig. **283**). The lateral extension of the inferior part of the facial recess is limited by the chorda, which runs obliquely down toward the facial nerve, making the chorda-facial angle smaller (Fig. **284**). With gradual drilling of the bone along the facial nerve, the atticotympanotomy opening gradually extends medially. It can now be extended along the facial nerve down to the hypotympanum (Fig. **285**) as far as possible, depending on the course of the chorda tympani (Fig. **286**).

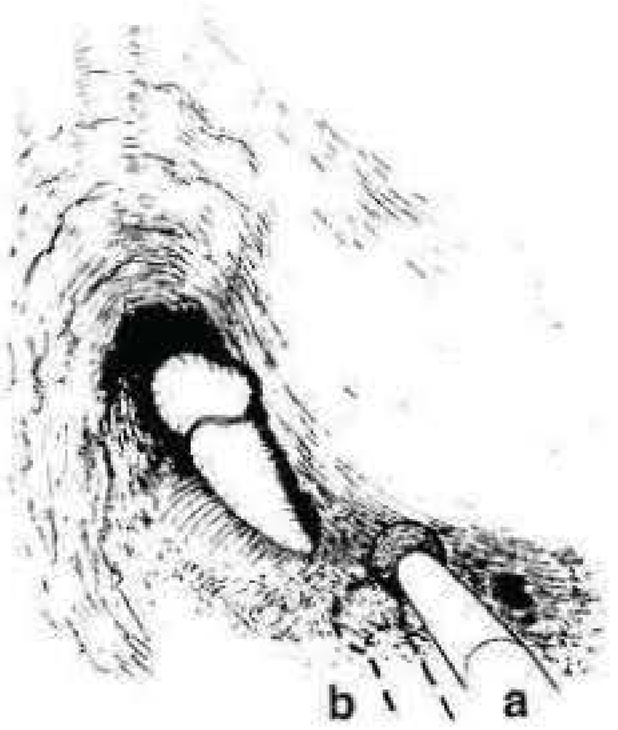


Fig. 278 **Posterior atticotympanotomy.** Initial drilling with a diamond drill behind the posterior buttress.
a Lateral route to the facial recess, starting the drilling laterally to the incudal fossa and just inferior to the posterior buttress (solid burr).
b Medial route, starting the drilling medially in the facial recess, initially exposing the facial nerve (dashed burr)

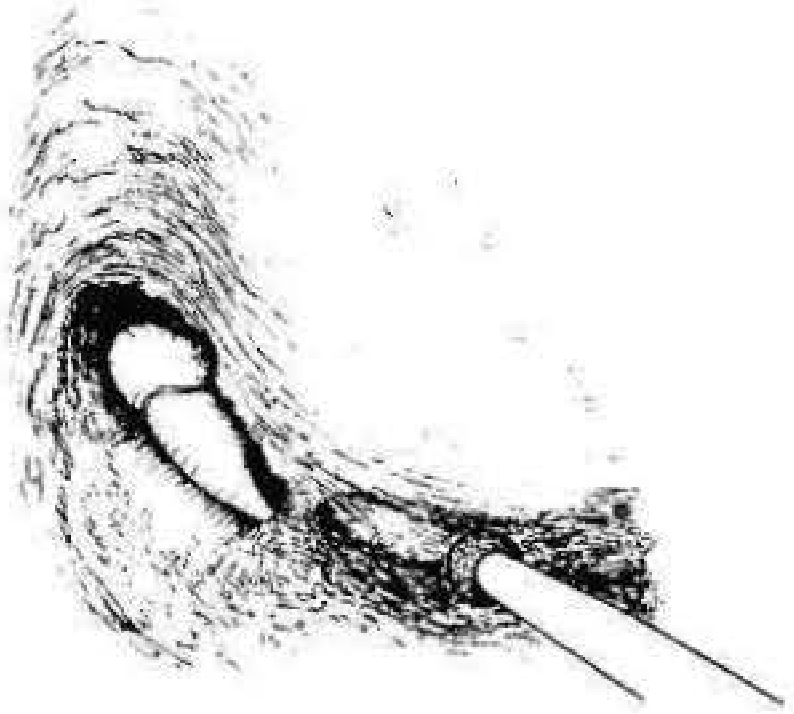


Fig. 279 **The lateral route through the facial recess.** Behind the broad posterior buttress, a small hole is drilled laterally in the facial recess

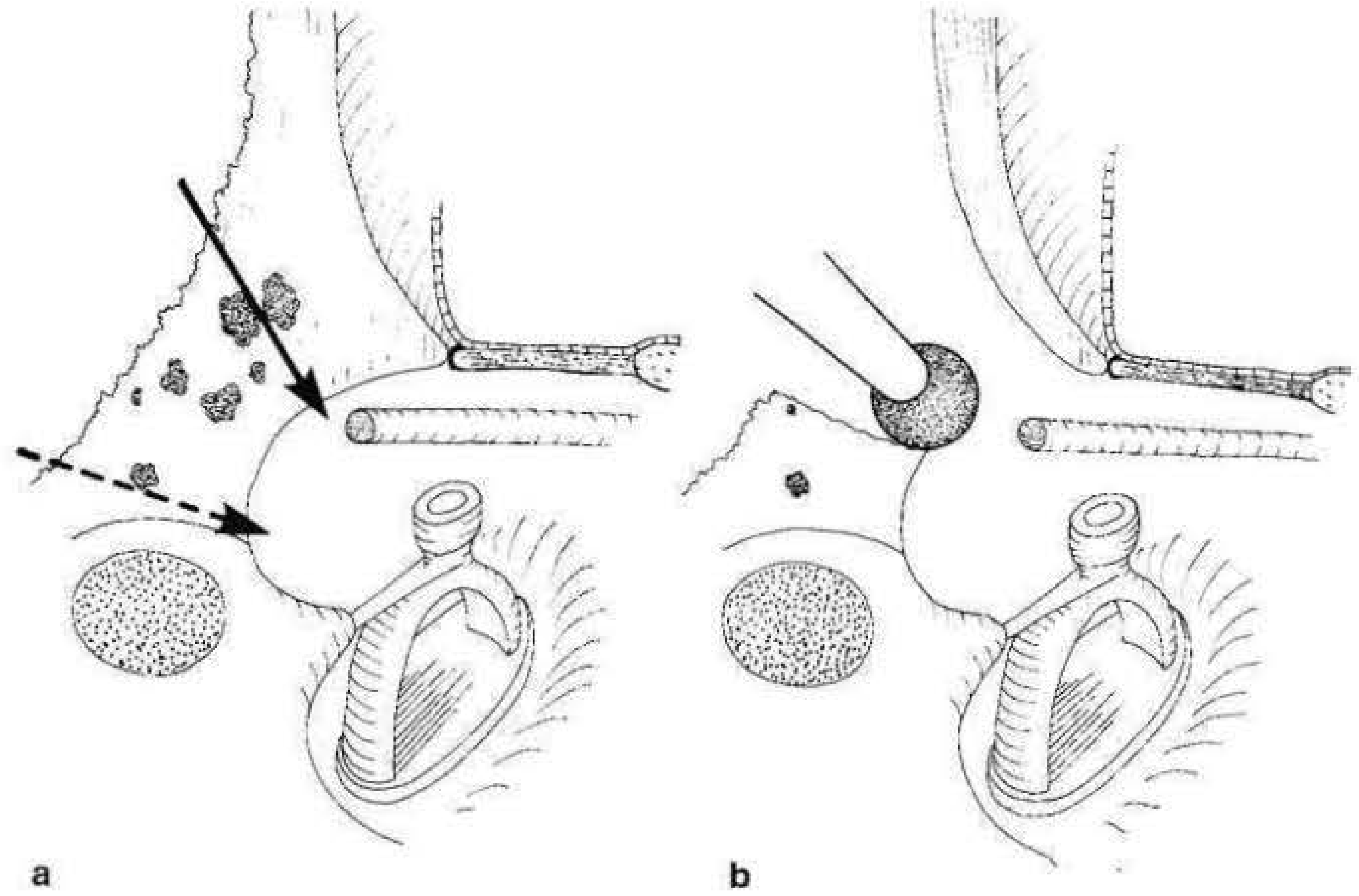


Fig. **280** **Side view of the facial recess, illustrating the lateral and medial routes superior to the chordal eminence.**

a The lateral route through the facial recess starts with thinning of the posterior ear canal wall (solid arrow) inferior to the buttress. The direction of the medial route through the facial recess is shown by the dashed (dashed arrow).

b The lateral route through the facial recess. A hole is drilled laterally into the facial recess making the posterior ear canal wall thin

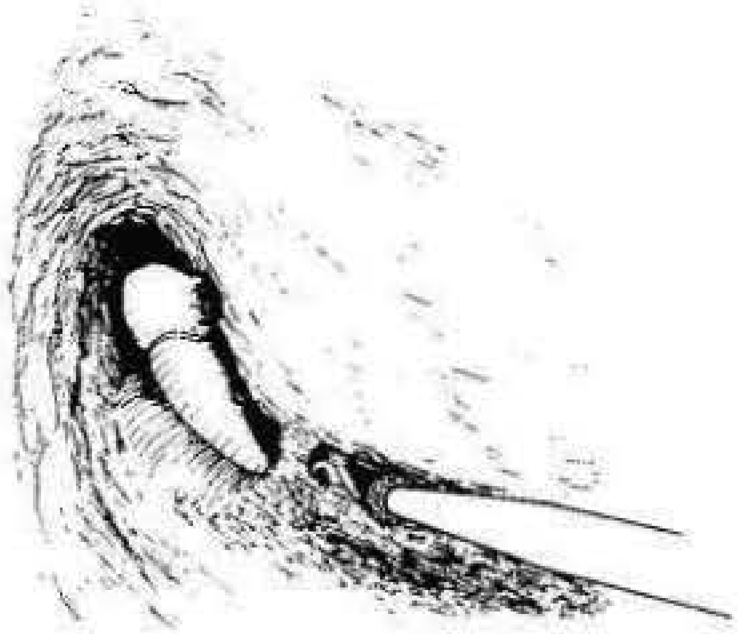


Fig. **281** **The lateral route.** The facial recess is enlarged by careful drilling along the posterior ear canal in a search for the tympanic chorda. The lateral part of the stapes and the stapedius muscle tendon are visible

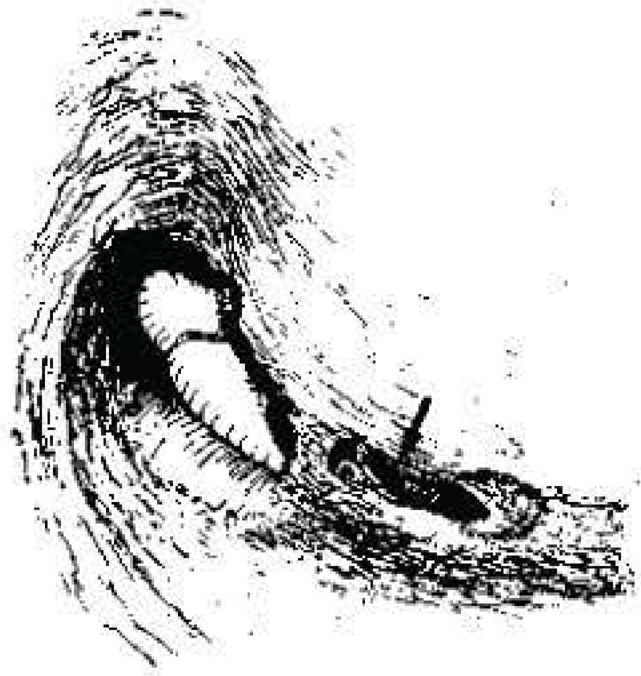


Fig. **282** The chorda tympani is exposed inferior to the incudostapedial joint (arrow)

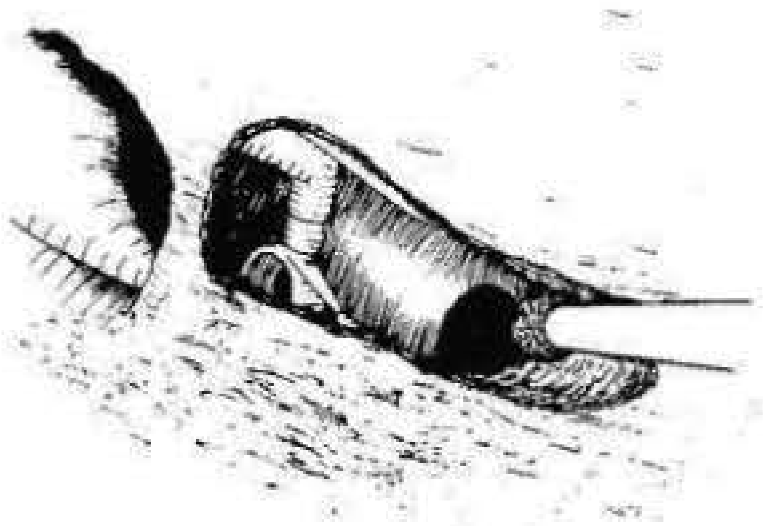


Fig. **283** Further drilling inferiorly along the course of the chorda tympani enlarges the facial recess and exposes the posterior tympanum, especially the round window niche

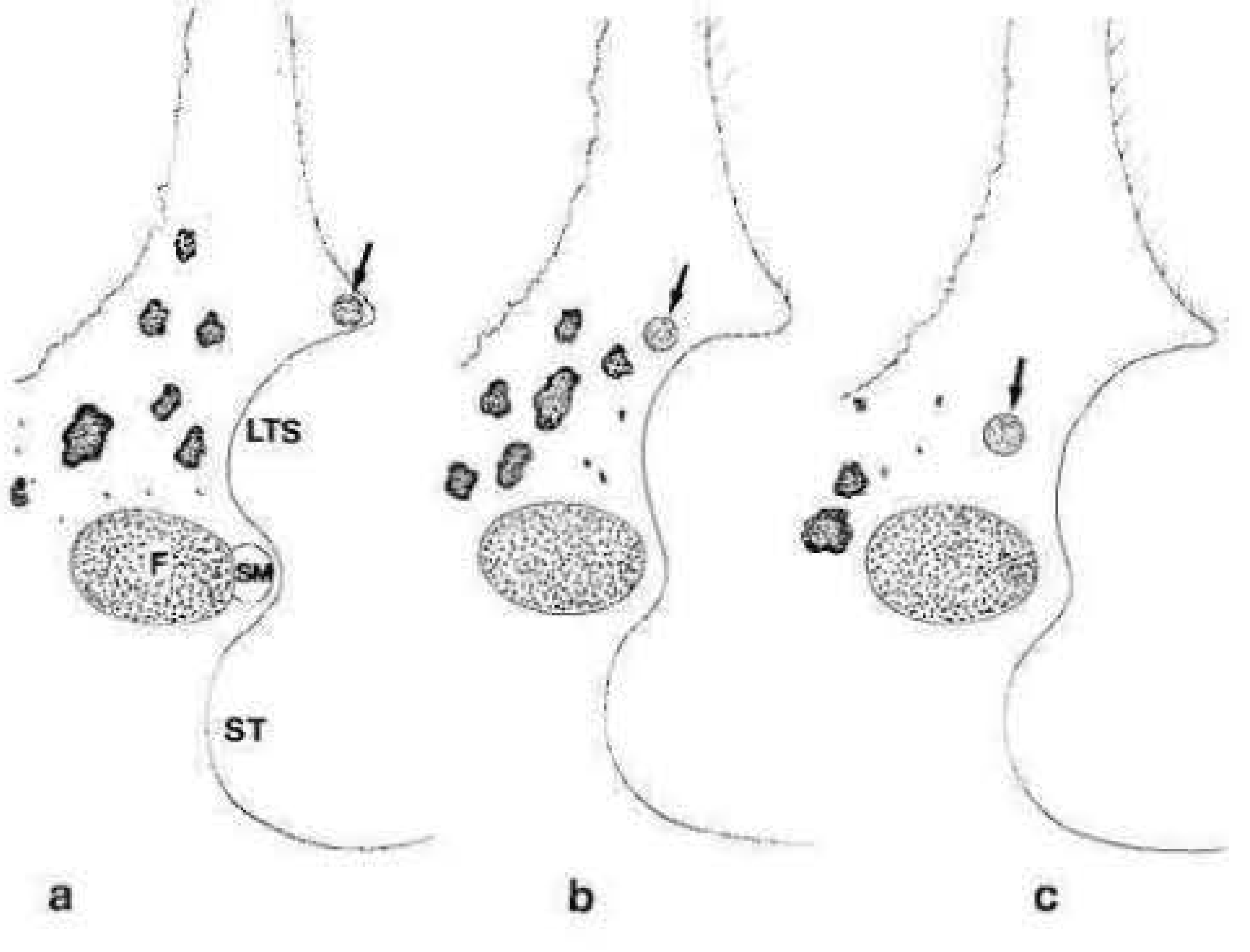


Fig. **284** **Side view of the facial recess, illustrating the position of the chorda tympani within the facial recess.**

a At the level of the chordal eminence, the chorda is located exactly at the level of the bony annulus. The facial nerve (F) and the stapedius muscle (SM) make the medial border of the facial recess somewhat inferior to the pyramidal eminence. LTS: lateral tympanic sinus; ST: sinus tympani.

b At the level of the round window, the distance from the facial nerve to the chorda tympani is smaller.

c In the hypotympanic region, before its entrance into the facial nerve, the space between the chorda and the lateral surface of the facial nerve is very small. There are usually no air cells at this level

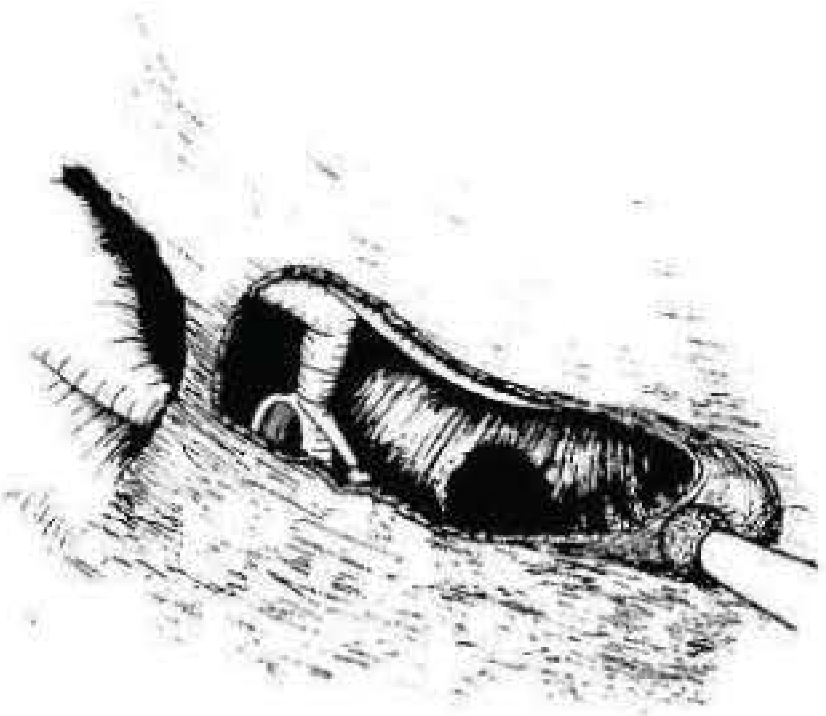


Fig. **285** Further extension of the facial recess inferior to the level of the round window

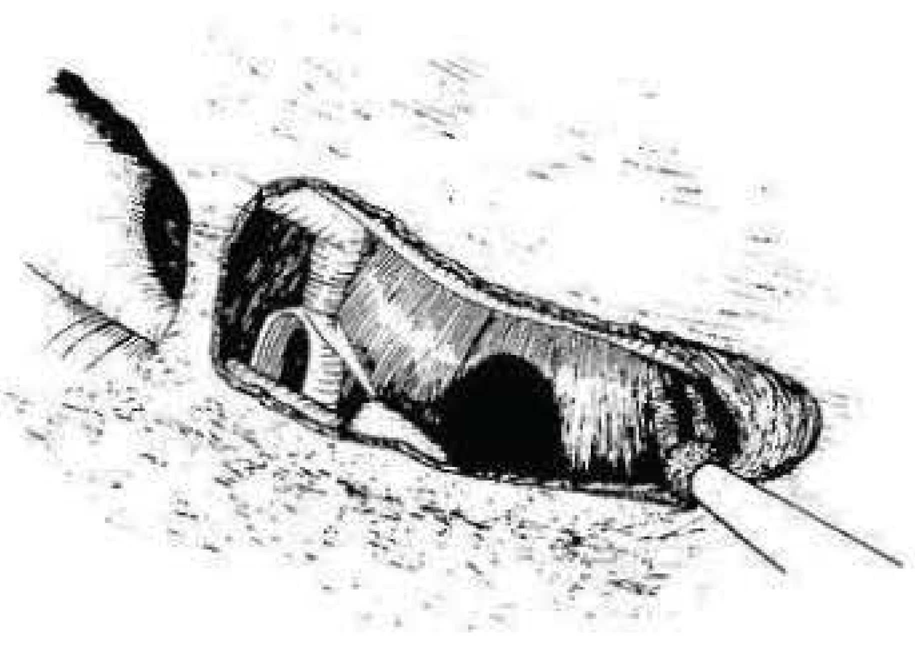


Fig. **286** The inferior limit of the facial recess at the level of the entrance of the chorda tympani into the facial nerve

The facial recess can be further widened by drilling the bone from the lateral aspect of the facial nerve (Fig. **286**). If necessary, complete skeletonization of the facial nerve or even decompression of its lateral and anterior aspects can be performed (Fig. **287**) at the level of the external genu and along its vertical segment until the junction of the chorda tympani with the facial nerve. Sometimes "barber-poling" of the facial nerve (Nelson 1982) is necessary to gain maximal exposure without damaging any surrounding structures. This term describes the thinning of the bone covering the facial nerve in a barber-pole fashion: 1) the vertical portion of the mastoid segment at the junction of the chorda with the facial nerve is skeletonized and unroofed on its *posterior* aspect. In this way, the chorda tympani is saved (Fig. **288**). 2) At the external genu, the facial nerve is unroofed on its *lateral and anterior* aspects. Drilling on the posterior aspect of the facial nerve at this level results in fenestration of the posterior or lateral semicircular canal, or both. 3) The horizontal segment is unroofed on its lateral and inferior aspects, but this latter part of the procedure is applied only in decompression of the facial nerve.

Barber-poling the facial nerve is sometimes necessary to enlarge the facial recess in cases of cholesteatoma. In decompression of the facial nerve, the procedure is very useful (Nelson 1983). It is also useful in cases in which there is difficulty in recognizing the extent of the facial recess, and in variations of the course of the facial nerve.

The facial recess is very variable. The bone can be sclerotic without any cells (Fig. **289a**) (Sheehy 1970 b), and in such cases the drilling is difficult and troublesome. The bone covering the facial nerve can include several air cells, some of them relatively large, and in such cases, by exenterating these air cells, the posterior atticotympanotomy is relatively easy (Fig. **289b**). Sometimes the bone within the

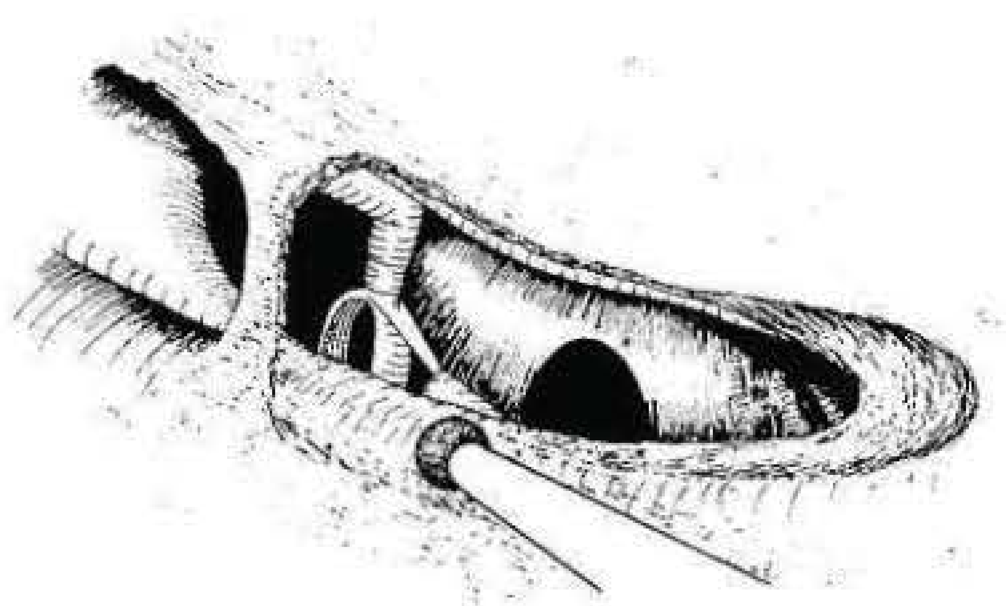


Fig. **287** Further enlargement of the facial recess by removal of the bone along the facial nerve, starting the drilling at the horizontal part of the facial nerve, and continuing toward the external genu and further inferiorly, along the vertical part of the facial nerve

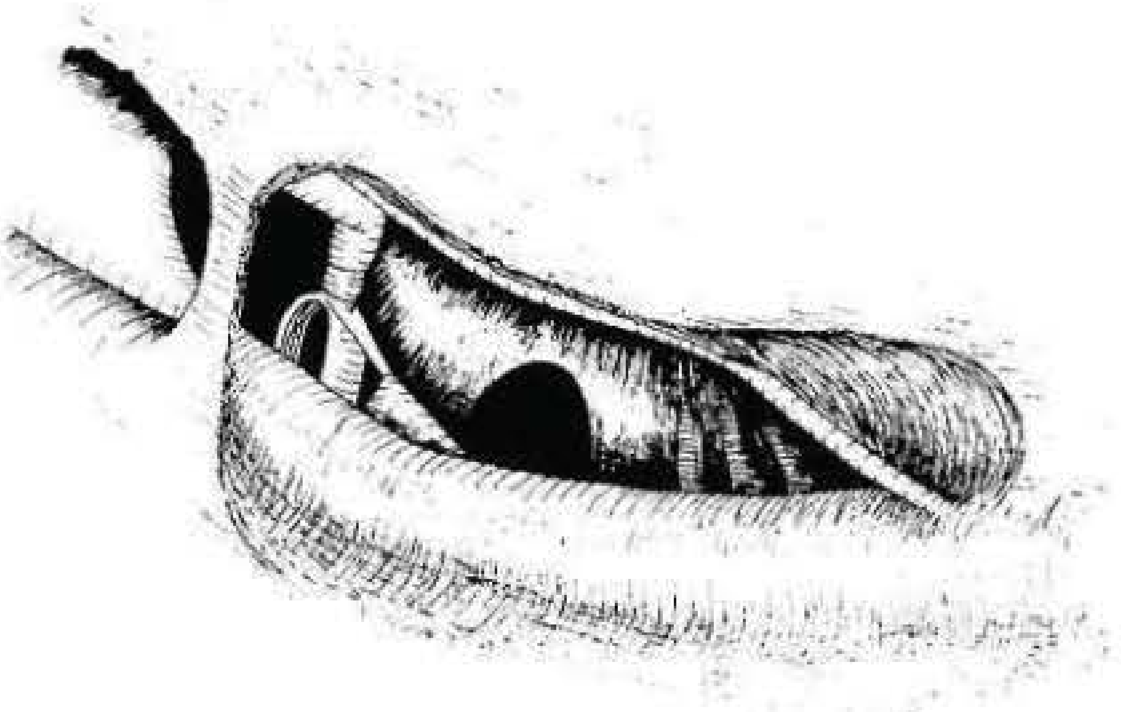


Fig. **288** **Barber-poling of the facial nerve** in order to decompress the nerve and enlarge the facial recess. At the level of the vertical segment, inferior to the posterior semicircular canal and the level of the entrance of the chorda into the facial nerve, the nerve is skeletonized and decompressed on its posterior aspect

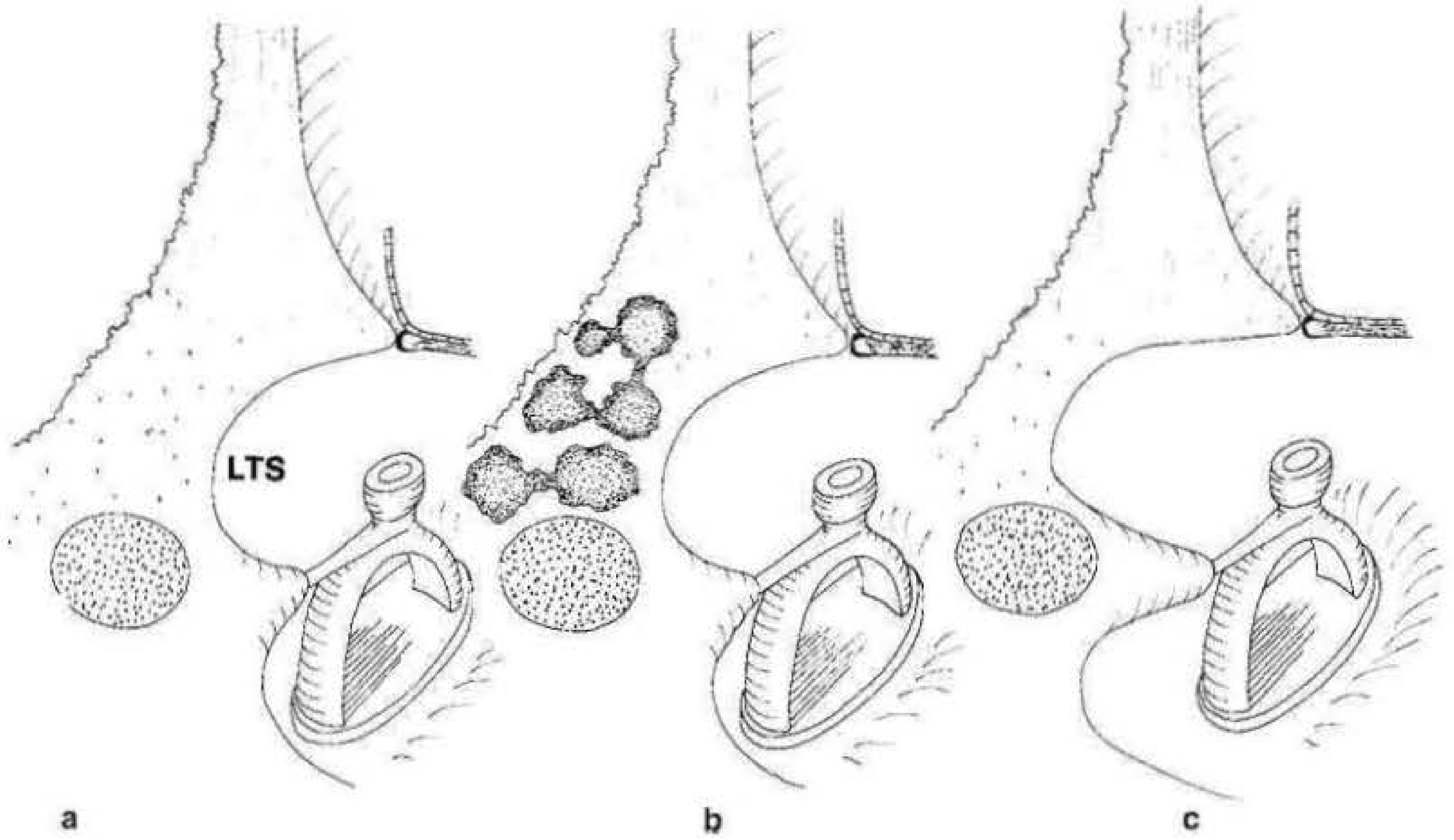


Fig. 289 **The variability of the compact bone and air cells within the facial recess.**
a The facial recess consists of thick compact bone, without cells.
b The bone forming the facial recess contains relatively large air cells which are easy to follow in order to enter the lateral tympanic sinus (LTS)
c The lateral tympanic sinus is large, and the bone covering the entrance to the facial recess is relatively thin, but compact. Here, too, the drilling through the facial recess is relatively easy

facial recess is thin because the depth of the lateral tympanic sinus and the facial sinus is large, and a posterior atticotympanotomy can again be relatively easy to perform in such cases (Fig. **289c**).

2. **The medial route.** Skeletonizing the facial nerve (and sometimes even decompressing it) at the external genu is necessary when the facial recess is entered medially close to the facial nerve (Fig. **280**). If the medial route to the facial recess is used, then the level of the short process of the incus is initially established. Inferior and medial to the short process of the incus, a small posterior buttress is left, and drilling is continued inferior to this buttress. The facial nerve is located. Through the opening into the facial recess, the stapedial arch is visualized (Figs. **290, 291**). With further drilling along the facial nerve, the nerve is skeletonized down to the hypotympanum, and at the same time the facial recess is extended laterally, with the chorda tympani being identified and followed toward its entrance into the facial nerve. Finally, the small residual triangle of bone between the facial nerve and the chorda tympani is drilled away (Fig. **292**), completing the posterior atticotympanotomy through the medial route (Fig. **290b**).

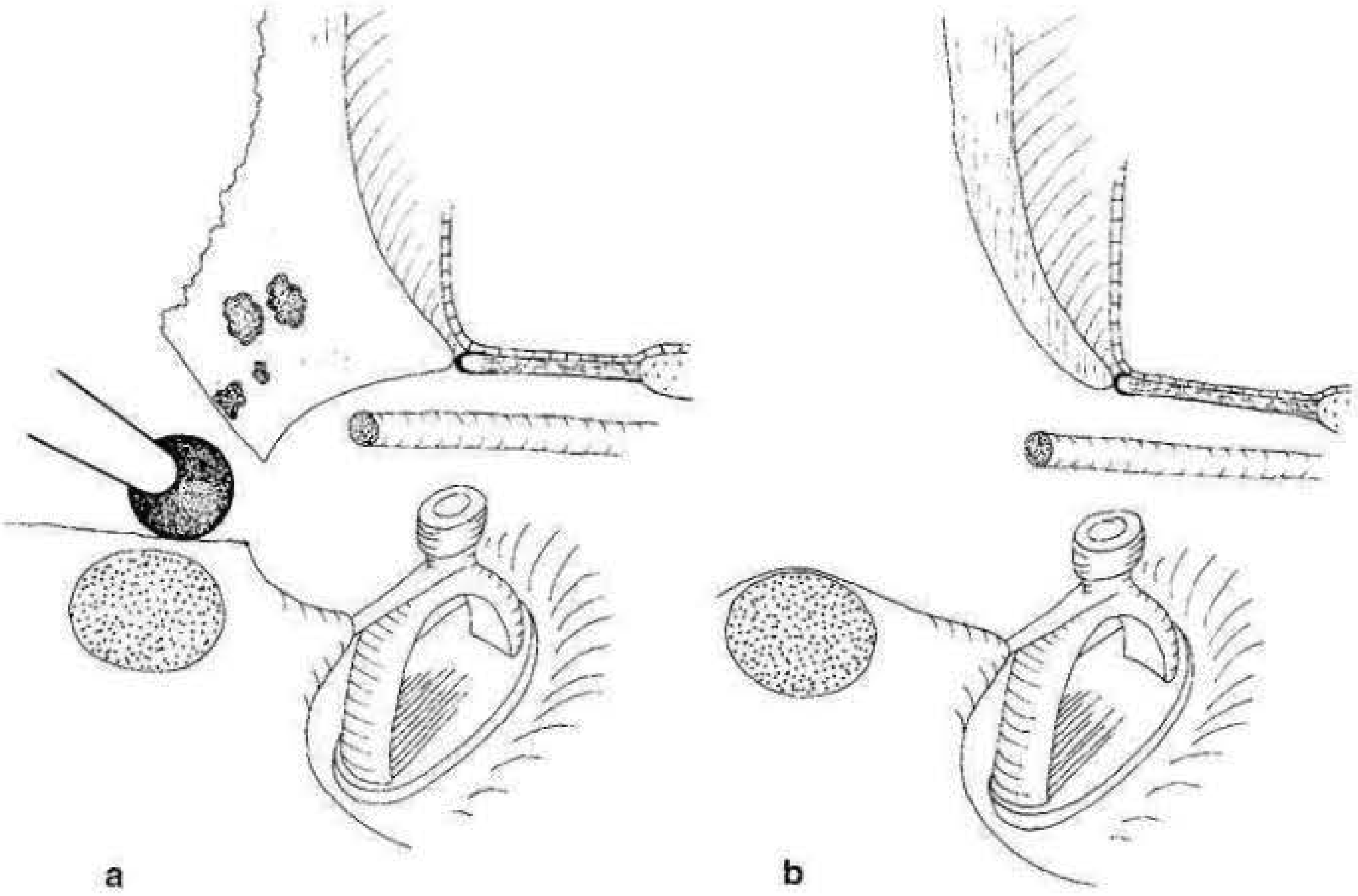
Removing the Posterior Buttress

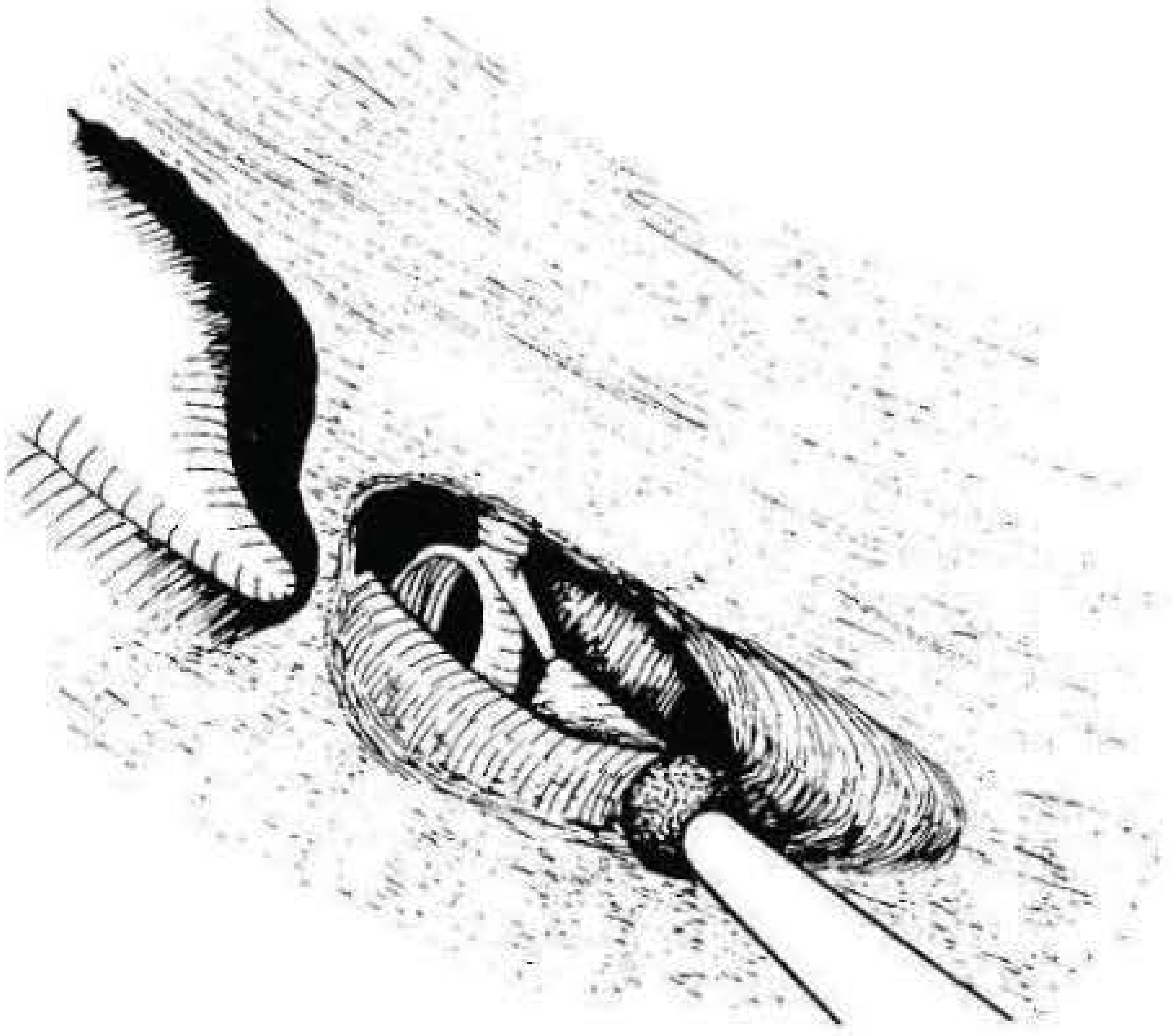
Removal of the buttress in cases with an intact ossicular chain is sometimes necessary in order to gain a better view of the horizontal portion of the facial nerve and the posterior tympanic sinus (Fig. **293**). Removing the buttress allows more complete and safer removal of the cholesteatoma, and the ossicular chain can still remain intact. A disadvantage of removing the buttress can be the lack of suspension of the short process of the incus, but it has not been demonstrated that this has any major effect on hearing.

Posterior Atticotympanotomy with Absent Incus

If the long process of the incus is defective or missing, or if the incus has been extracted before the posterior tympanotomy, then the thinning of the lateral attic wall starts at the level of the malleus head and continues toward the posterior buttress, which is removed, and the facial recess is then opened, with constant visualization of the horizontal part of the facial nerve being maintained (Fig. **294**). The thinning of the lateral attic wall is continued, allowing good enlargement of the tympanic

Fig. 290 **The medial route through the facial recess**
a The drilling is starting close to the posterior buttress and along the facial nerve, skeletonizing it at its external genu, and continuing drilling in inferior direction.
b Final status after completing the medial route, skeletonizing all bone covering the facial nerve and maximal thinning of the posterior ear canal wall





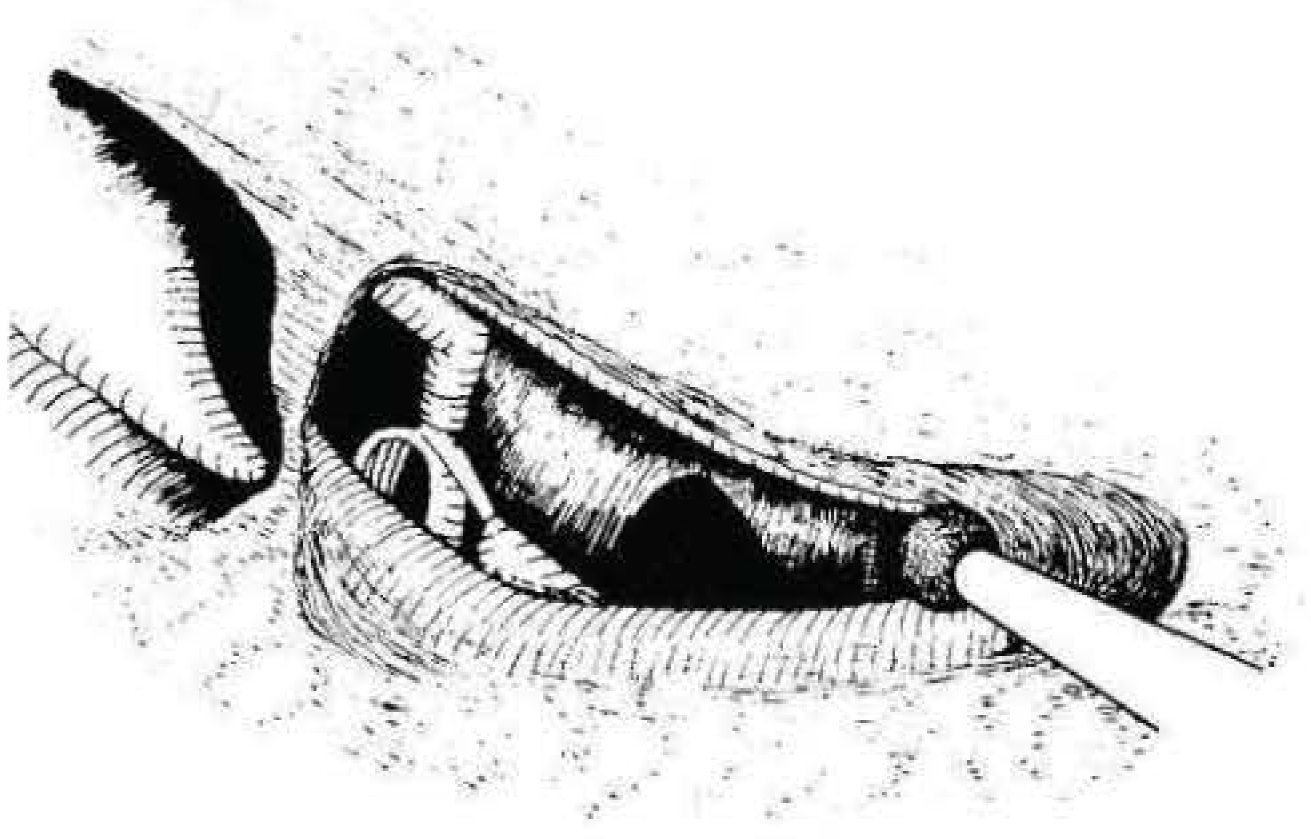
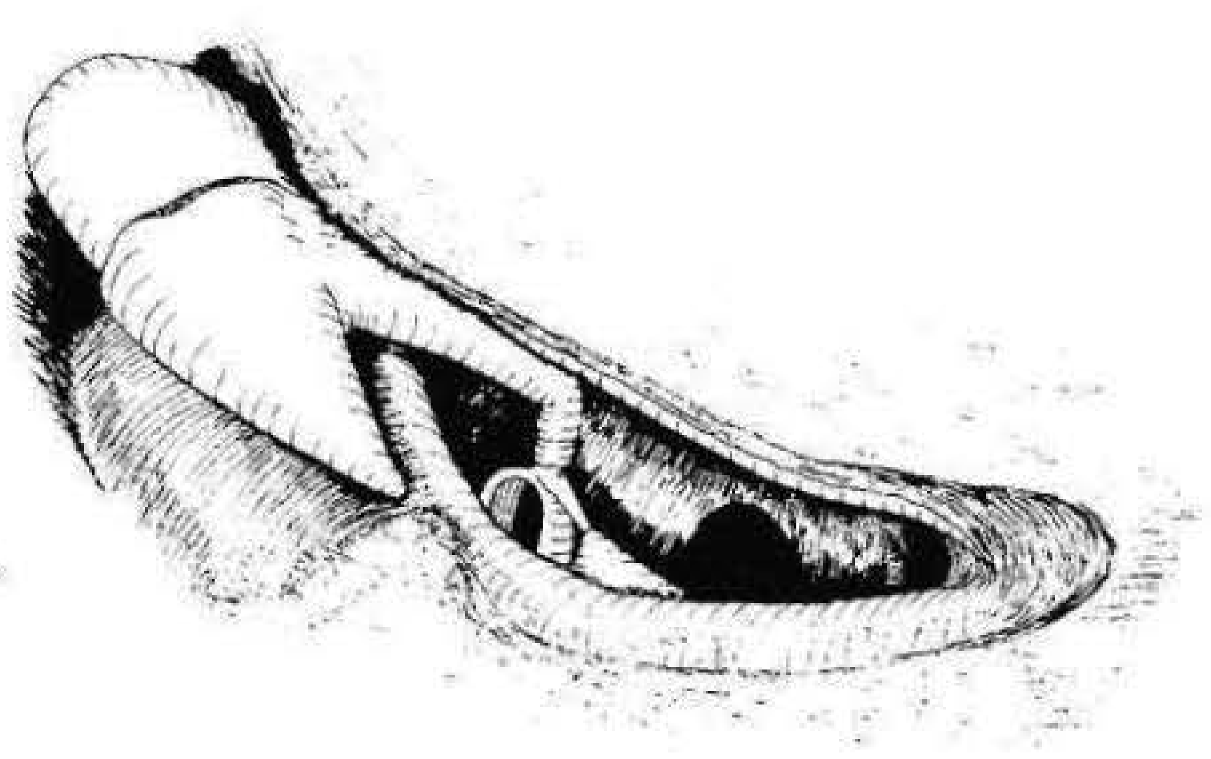


Fig. 291 **The medial route through the facial recess.** The short process of the incus and fossa incudis are exposed along the small posterior buttress. The drilling is started medially and inferiorly to the short process of the incus, removing the bone localized on the lateral semicircular canal and continuing medially, skeletonizing the external genu of the facial nerve with the pyramidal process. The drilling continues along the nerve in the inferior direction, toward the entrance of the chorda into the facial nerve

Fig. 292 The drilling along the facial nerve is nearly completed, and the lateral part of the bone has been removed up to the tympanic chorda, which is intact

Fig. 293 **Removal of the posterior buttress** in an ▷ intact ossicular chain allows better visualization of the posterior tympanum, especially the horizontal segment of the facial nerve, incus, and stapes



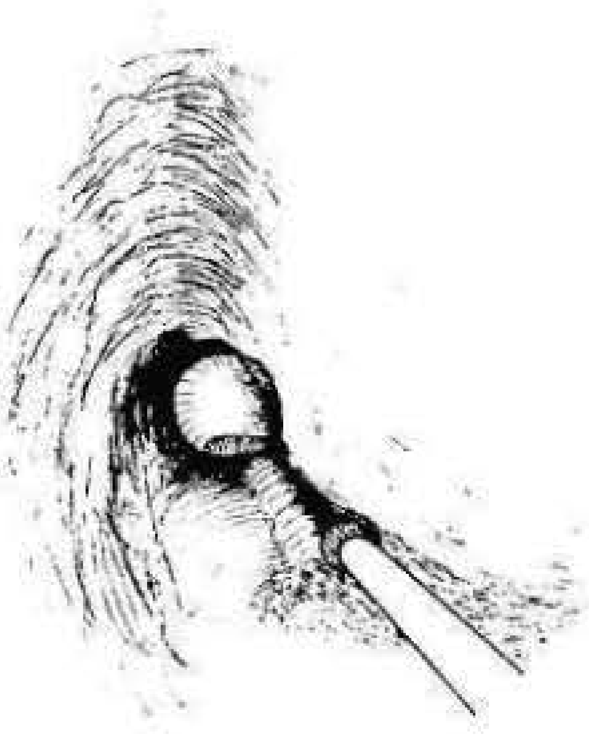


Fig. 294

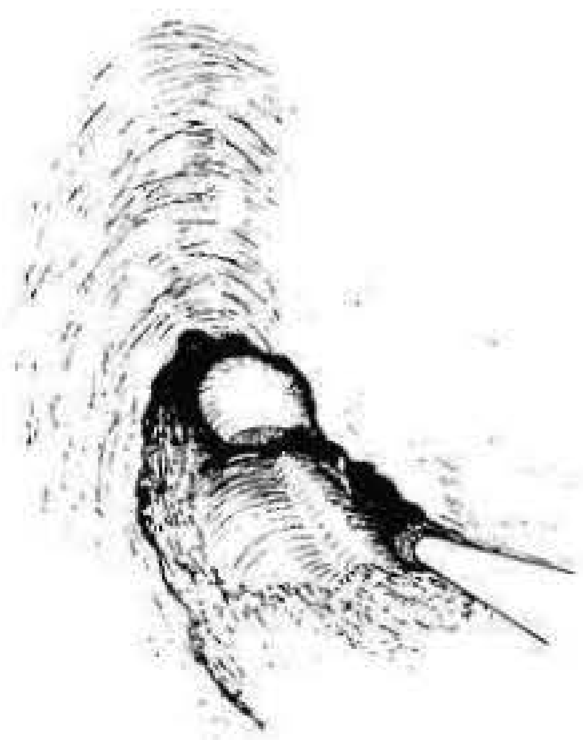


Fig. 295

Fig. 294 **Posterior atticotympanotomy with an absent incus.** The thinning of the lateral attic wall starts at the malleus head and continues toward the posterior buttress

Fig. 295 The isthmus tympani is wide open, and the posterior buttress has been removed

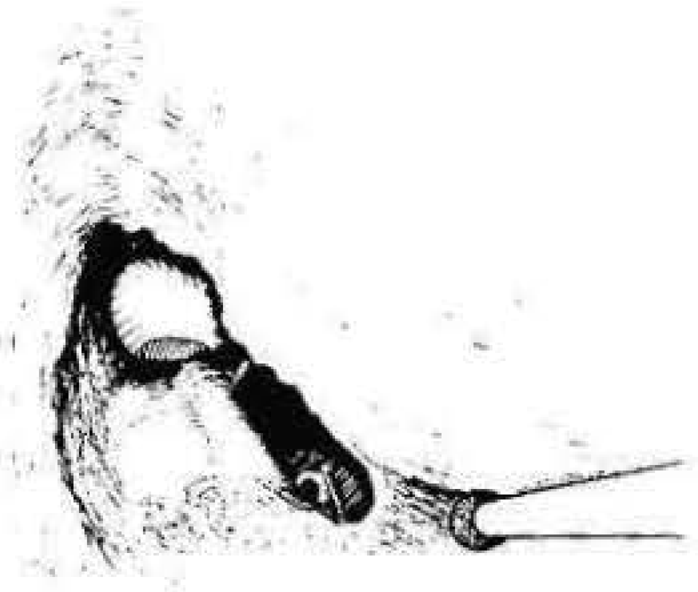


Fig. 296

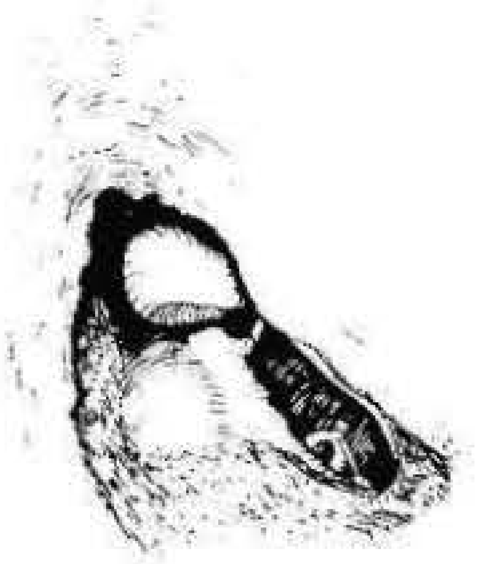


Fig. 297

Fig. 296 The posterior atticotympanotomy is extended inferiorly. The stapes is visualized

Fig. 297 Further enlargement of the posterior atticotympanotomy exposing the chorda

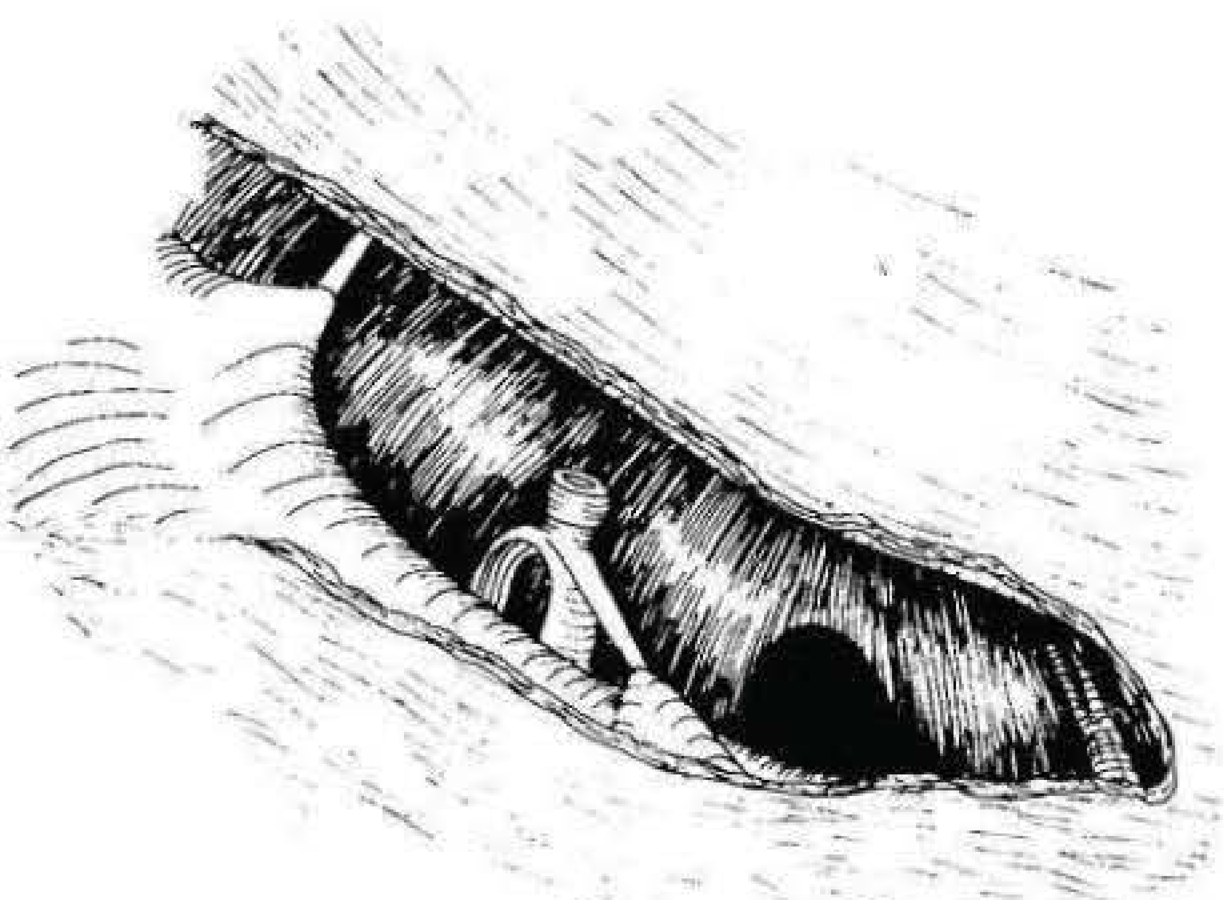


Fig. 298 The posterior atticotympanotomy is nearly complete. The chorda tympani is exposed. Part of hypotympanum and the posterior tympanum are visible

isthmus (Fig. **295**). With further drilling in an inferior direction, the stapes is visualized (Fig. **296**), and the external genu of the facial nerve eventually becomes visible (Fig. **297**). The facial recess is now extended laterally toward the chorda tympani, which is exposed. The access to the tympanic cavity is larger here than in cases with an intact ossicular chain (Fig. **298**).

Complications of Posterior Atticotomy

In cases with an intact ossicular chain, drilling in the lateral attic to achieve a thin ear canal wall can be troublesome and dangerous if the burr comes into contact with the intact chain. In order to prevent a high-tone sensorineural hearing loss, a diamond burr is always used in this region, and it is moved gently along the posterior circumference of the lateral attic wall.

During drilling of the facial recess with an intact ossicular chain, the short process of the incus and the fossa incudis needs to be located. The posterior buttress prevents contact between the burr and the incus, but it hampers the view of the tympanic sinus.

The risk of damage to the chorda tympani in the lateral route through the facial recess, or damage to the facial nerve in the medial route, always exists. Practice on many temporal bones is required in order to perform posterior atticotympanotomy properly and quickly. Even the experienced ear surgeon performing posterior atticotympanotomy may occasionally have problems drilling within the facial recess and avoiding exposure of the facial nerve. A dehiscent facial nerve canal in its horizontal course was found in 22% of cases with cholesteatoma, and these dehiscences were either due to bone resorption by the disease or were congenital in origin (Jansen 1963). Even an experienced surgeon who performs posterior atticotympanotomy may injure the facial nerve in a small percentage of cases, but the risk to the facial nerve is much higher when surgery is performed by an inexperienced surgeon.

During lateral drilling, the chorda is relatively frequently damaged, and the drill can touch the incudostapedial joint, causing sensorineural hearing loss.

In order to avoid sensorineural hearing loss and to provide better access to the facial nerve, several surgeons recommend disruption of an intact ossicular chain before drilling (Smyth et al. 1971). The present author (Tos and Lau 1991) has documented that the long-term hearing results in cases with cholesteatoma and a disrupted ossicular chain are poorer than in cases with an intact ossicular chain (Volume

1, Fig. **711**), and such disruption is therefore not recommended only in order to perform a posterior atticotympanotomy. In such cases, it is preferable to perform a canal wall–down mastoidectomy and keep the ossicular chain intact.

Extended Posterior Atticotympanotomy, Transmastoid Hypotympanotomy

In cases requiring extensive access to the tympanic cavity, such as glomus tympanicum tumors, glomus jugulare tumors, facial nerve neurinomas, or even cholesteatomas involving the hypotympanum, the chorda tympani is sacrificed and the posterior atticotympanotomy is extended inferiorly and anteriorly. This procedure is called *hypotympanotomy* by Jansen (1972), but the present author suggests the term *transmastoid hypotympanotomy* to differentiate it from *transmeatal hypotympanotomy* (Volume 1, Figs. **192–204**).

When a large atticotympanotomy is desired, the chorda can be sacrificed at the chordal eminence (Fig. **299**). With the chorda tympani as the guide, the drilling through the facial recess is faster, and a large atticotympanotomy is performed before further removal of the bone along the inferior bony annuhis. The exit of the chorda from the facial nerve is located, and the facial nerve is skeletonized. The drilling can then continue far anteriorly, while the lower prominence of the promontory at the hypotympanic sinus is inspected. The drilling is continued into the tympanic bone (Fig. **300**). With further drilling anteriorly, the anterior part of the hypotympanum is reached (Fig. **301**), and finally the inferior transmastoid hypotympanotomy is completed (Fig. **302**).

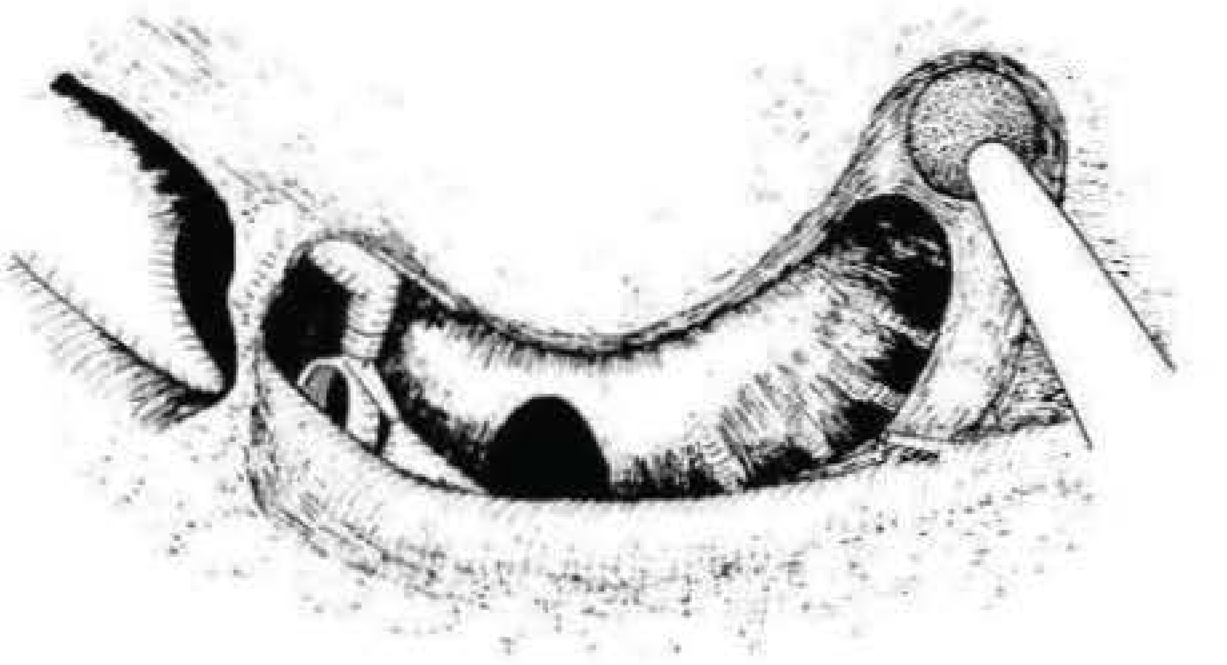


Fig. **299** **Transmastoid hypotympanotomy.** The chorda is sacrificed, and the posterior atticotympanotomy is extended toward the hypotympanum by drilling the tympanic bone. Posteriorly, the facial nerve is exposed

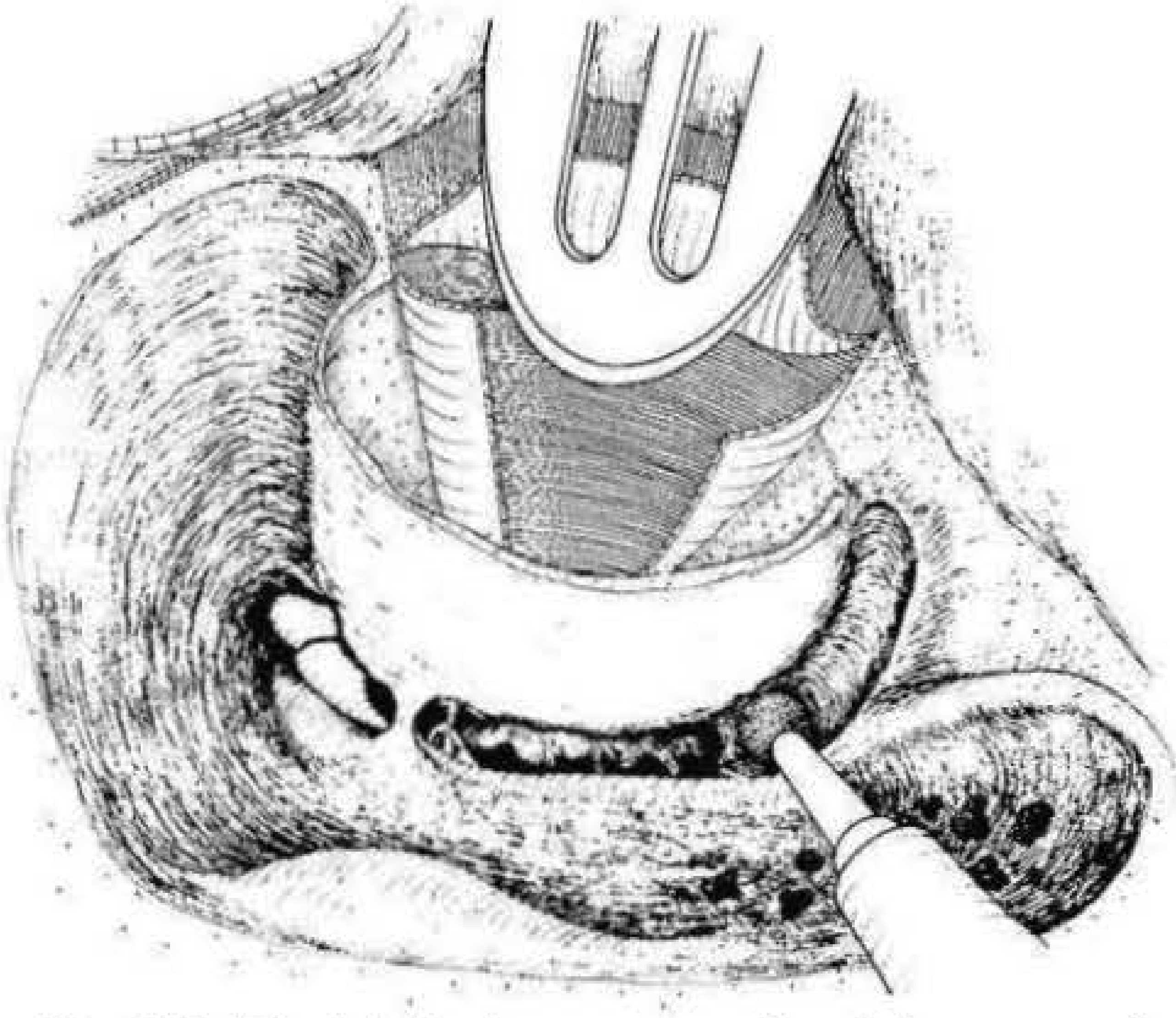


Fig. **300** The inferior bony ear canal wall is preserved and the hypotympanum exposed

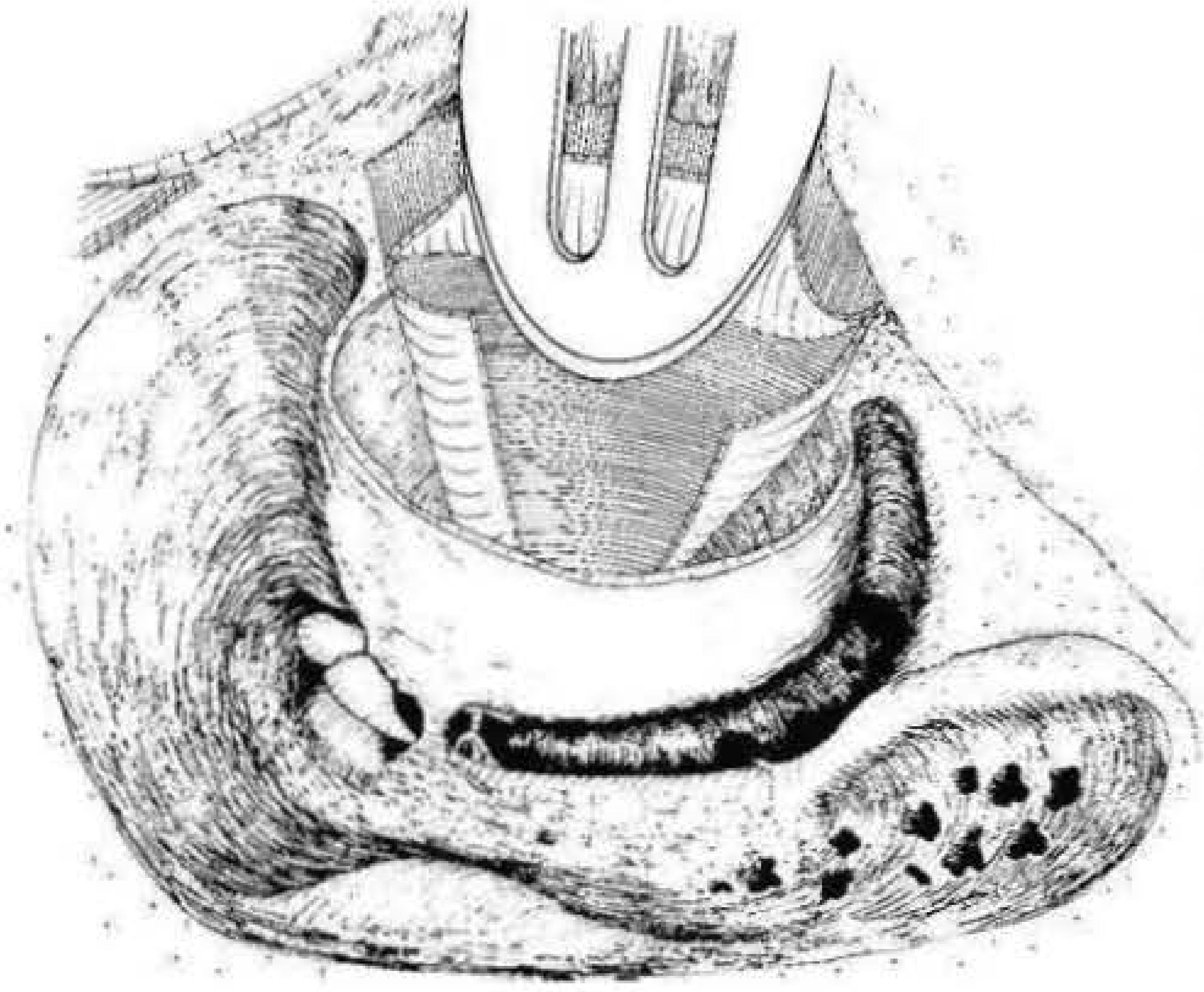


Fig. **301** The drilling is continued far anteriorly. The hypotympanic cells are exposed

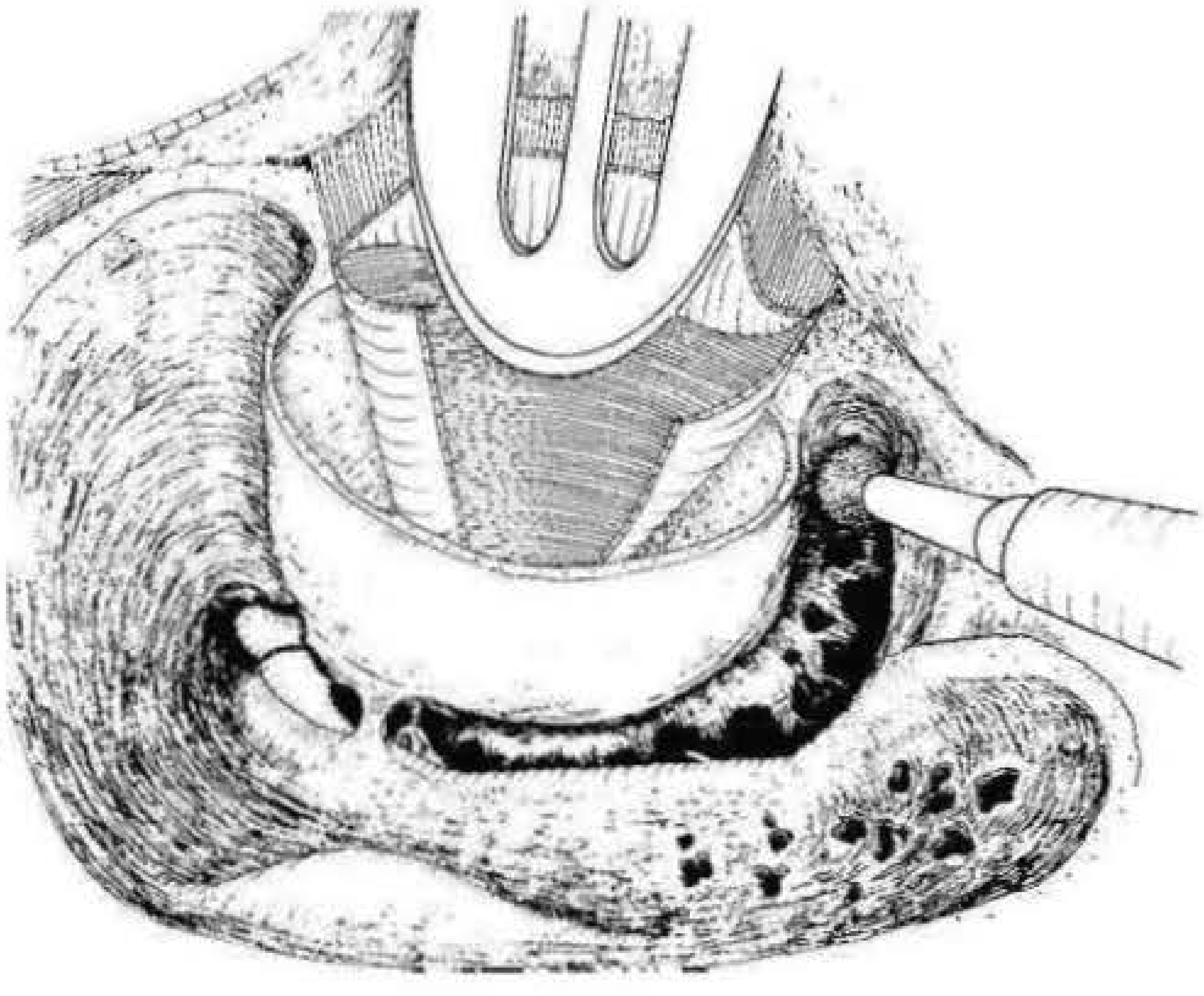


Fig. **302** The transmastoid hypotympanotomy is complete

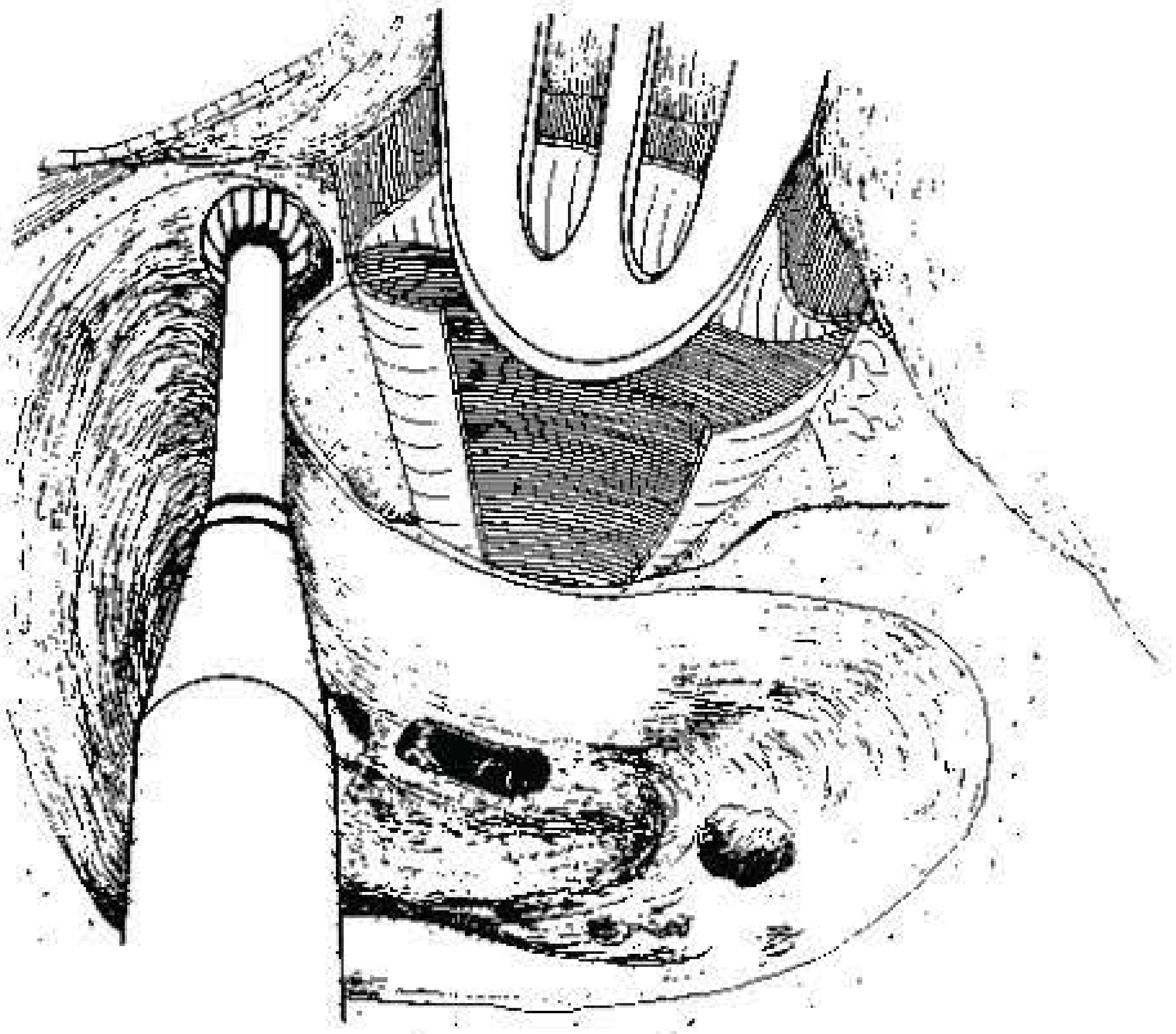


Fig. **303** **Anterior extension of the mastoidectomy.** The cutting burr is held toward the zygomatic region of the temporal bone, and the drilling takes place from lateral to medial

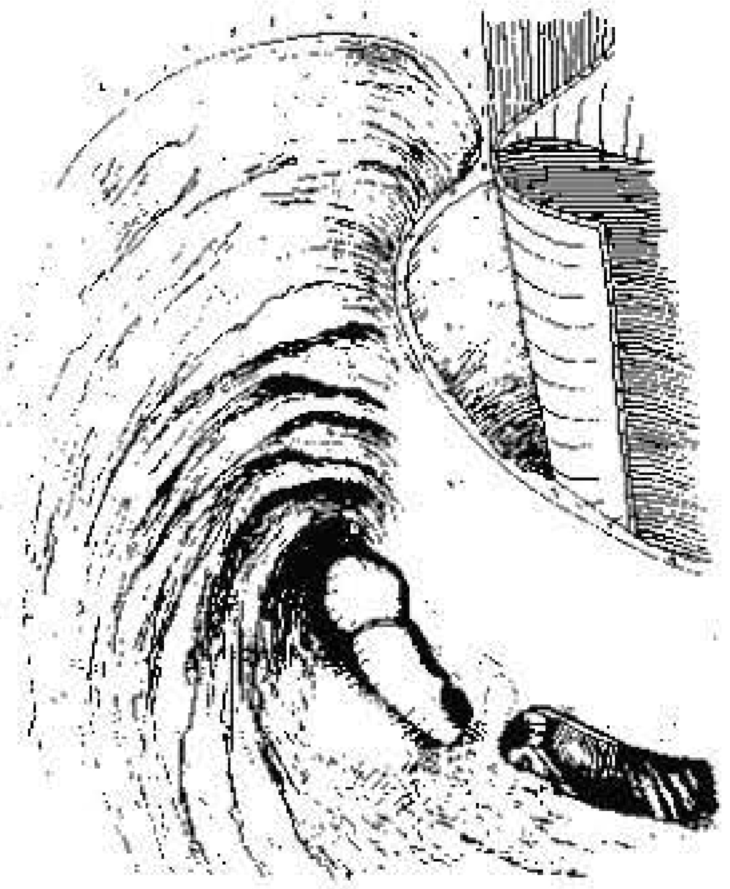


Fig. **304** The mastoid cavity has been enlarged anteriorly. The mastoid tegmen is exposed, but several bony overhangs have to be drilled away

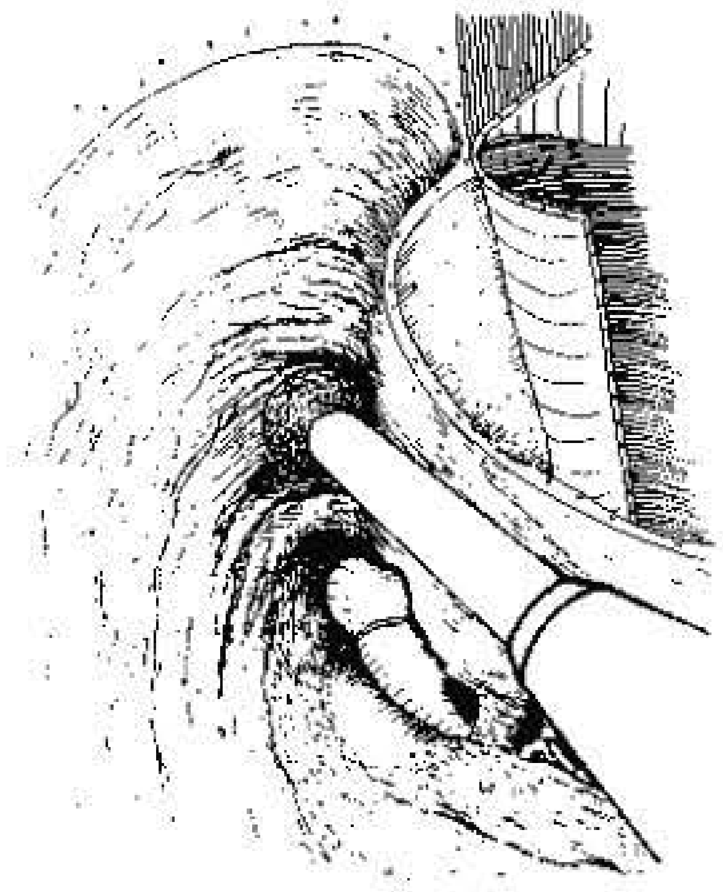


Fig. **305** Drilling of bony overhangs using a diamond burr, enlarging the most anterior part of the mastoid cavity

Transcortical Anterior Atticotympanotomy

The term *transmeatal atticotympanotomy,* denoting transmeatal removal of the bone in the anterior attic, was already used by Farrior (1968, 1969) in his method of transmeatal anterior atticotympanotomy and posterior mastoidectomy (Fig. **47**). The term *transcortical anterior atticotympanotomy* is used by the present author to describe transcortical (transmastoid) removal of the bone in the anterior attic and epitympanic sinus in order to enter the anterior part of the tympanic cavity and the tympanic orifice of the Eustachian tube. The term *atticoantrotomy* is more precise than the term *anterior tympanotomy,* which refers to the elevation of the anterior tympanomeatal flap (Volume 1, Chapter 7).

Anterior atticotympanotomy is an important procedure in classic intact canal wall mastoidectomy, with the main goal being to remove an attic cholesteatoma and create a connection to the tympanic cavity in order to facilitate postoperative ventilation of the mastoid cavity.

Anterior Enlargement of the Mastoid Cavity

In order to gain access to the anterior attic, a considerable amout of bone from the zygomatic region of the temporal bone should be removed, and the mastoid cavity should be maximally enlarged far anteriorly. Enlargement may sometimes extend as far anteriorly as the 2-o'clock position in order to remove all the cells and achieve the necessary space. All bone between the thin superior bony ear canal wall and mastoid tegmen laterally and the tegmen tympani medially has to be removed (Fig. **303**). The drilling starts laterally, using a cutting burr directed toward the zygomatic region. Drilling continues medially, gradually enlarging the space between the superior ear canal wall and the tegmen tympani (Fig. **304**). When one is approaching the lateral wall of the anterior attic, a diamond burr is used, and the bone lateral to the malleus is removed (Fig. **305**). Further removal of bone is often necessary in order to enlarge the access, and this can be done by extreme thinning of the bony plate covering the middle fossa dura and the anterior region of the mastoid tegmen (Fig. **306**). Sometimes it is necessary to expose the dura in order to gain enough space.

In ears with cholesteatoma, the pneumatization is usually much reduced, and the space between the mastoid tegmen and superior ear canal can be narrow. The dura is often low, which in the author's opinion is one of the consequences of diminished pneumatization, as described in Chapter 3. Access to the anterior attic, particularly in cases of cholesteatoma, is therefore reduced, and much drilling far posterior to the actual pathology, including skeletonization of the sigmoid sinus and even exposure of the sinus, is sometimes necessary to provide access to the anterior attic.

Unroofing the Attic

After further removal of bone in the zygomatic region, a bony overhang of the anterior attic covering the malleus head remains. This is removed using a diamond burr (Fig. **307**). Further enlargement of the anterior attic requires bone removal of the tegmen tympani (Fig. **308**). Finally, the anterior malleolar ligament becomes visible (Fig. **309**).

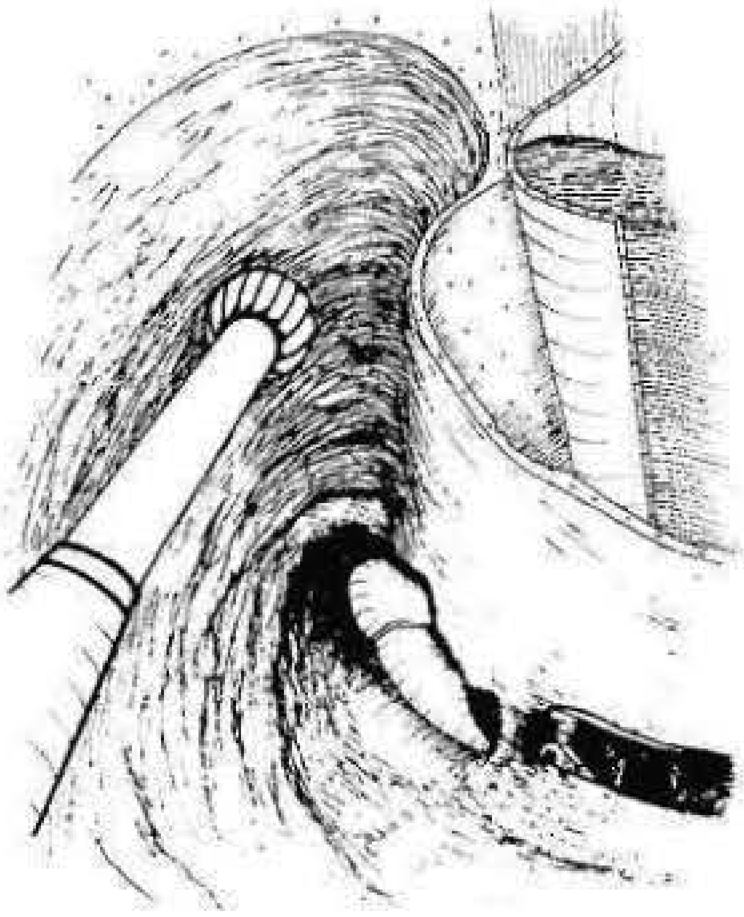


Fig. **306** Further enlargement of the anterior mastoid cavity by maximum thinning of the bony plate of the mastoid tegmen

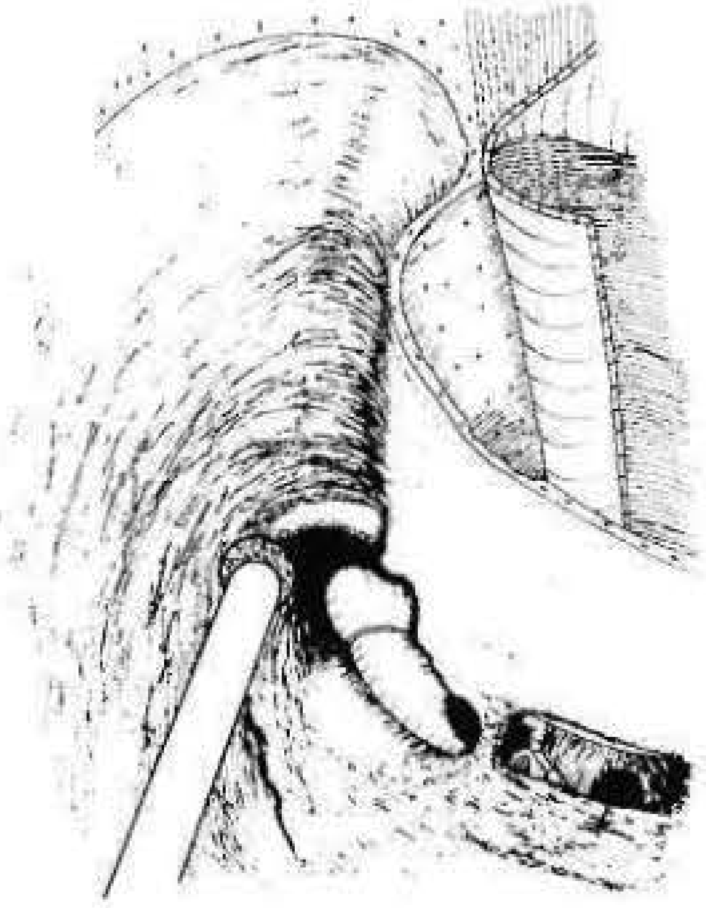


Fig. **307** **Unroofing of the attic.** With a diamond burr, the anterior part of the lateral attic wall is removed

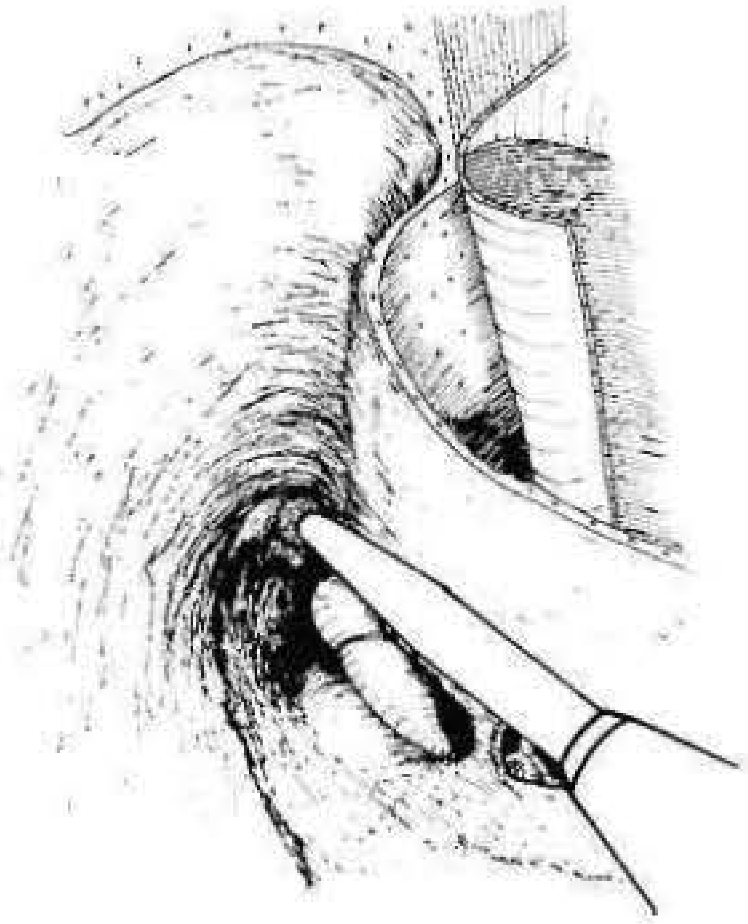


Fig. **308** Further removal of the overhang and enlargement of the anterior attic

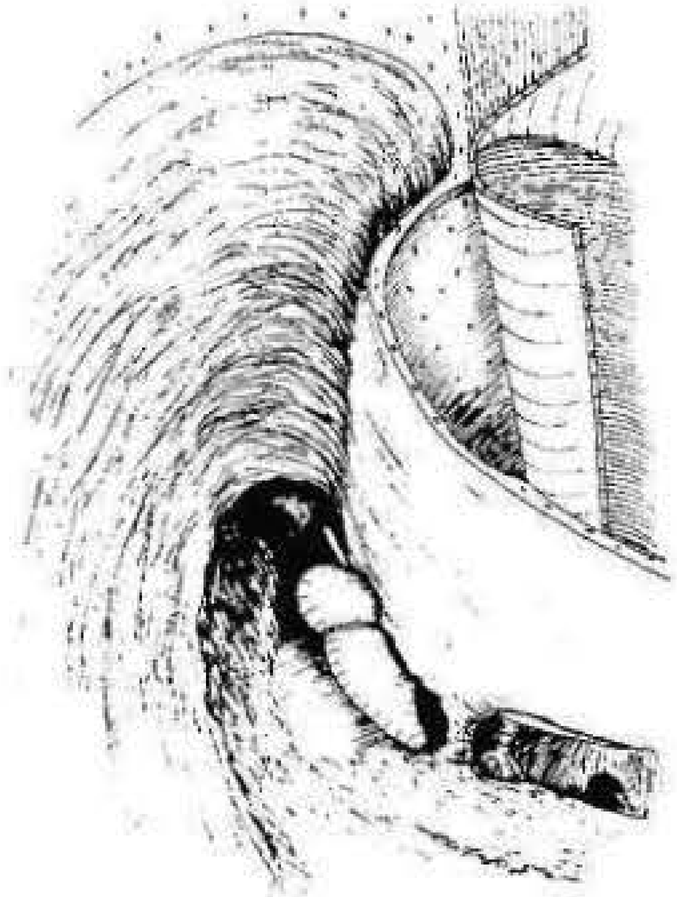


Fig. **309** The anterior malleolar ligament is now visible, ▷ and the space in the attic is enlarged

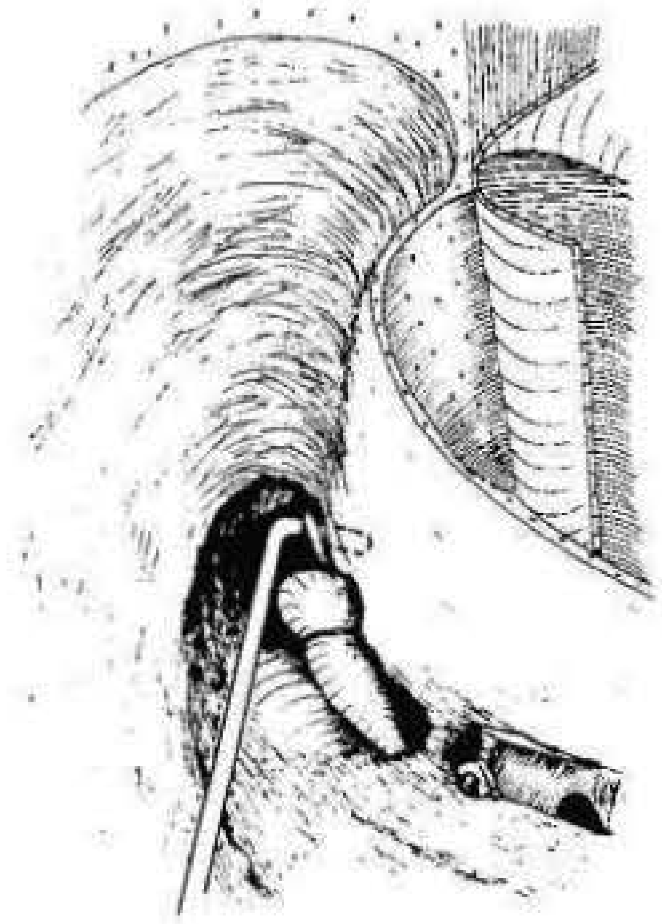


Fig. **310** With a curved instrument placed under the chorda tympani and under the anterior malleolar ligament toward the tube, the adhesions and mucosal folds are removed and turned over

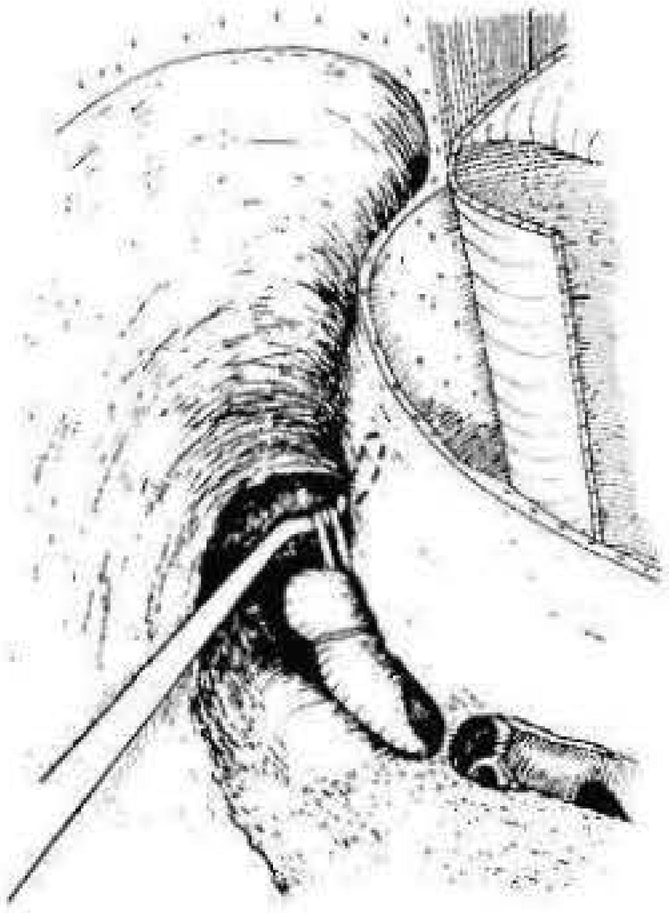


Fig. **311** Passage with a curved instrument under the malleolar fold toward the tube is possible, and will be further elaborated

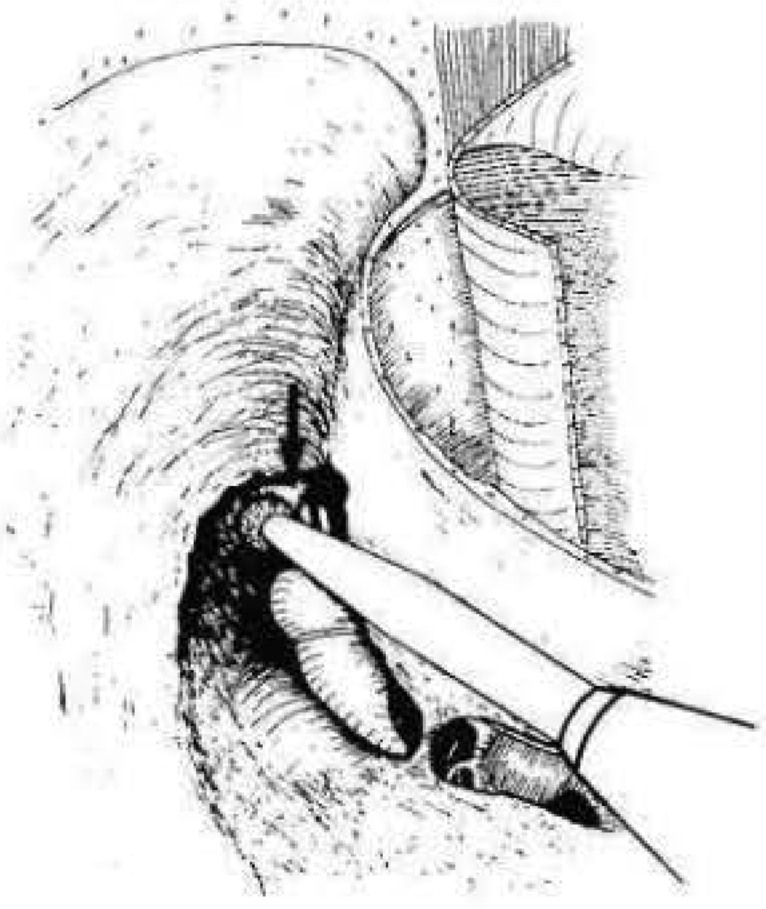


Fig. **312** Removal of the cog (arrow) and cleaning of the walls of the epitympanic sinus

Entering the Epitympanic Sinus

In order to ventilate the mastoid cavity in intact canal wall mastoidectomy, a widely patent connection between the supratubal recess and the attic needs to be provided. Both the bony overhangs from the tegmen tympani and a larger anterior bony plate (Morimitsu et al. 1989) or cog (Yamasoba et al. 1990)—separating the anterior attic from the supratubal recess—have to be removed. First, removal of the anterior tympanic fold can be achieved using an angled rougine (Fig. **310**). The rougine is placed medial to the anterior ligament and the chorda tympani, directed toward the Eustachian tube (Fig. **311**). Further drilling of the roof of the anterior attic is then performed, avoiding damage to the chorda tympani (Fig. **312**). With further drilling, the cog (Fig. **313**) is removed, connecting the attic and the epitympanic sinus with the superior part of the Eustachian tube. This is only possible by placing the head of the diamond burr under the chorda and continuing drilling in the direction of the Eustachian tube. The eminence of the tensor tympani muscle finally becomes visible. Final polishing of the enlarged attic wall, the tegmen tympani, and along the epitympanic sinus wall, is performed to enlarge the connection to the Eustachian tube (Fig. **314**). The connection between the attic and the Eustachian tube should be wide laterally, i. e., between the ear canal and the anterior ligament, and medially, i. e., between the chorda tympani and the medial attic wall (Fig. **315**).

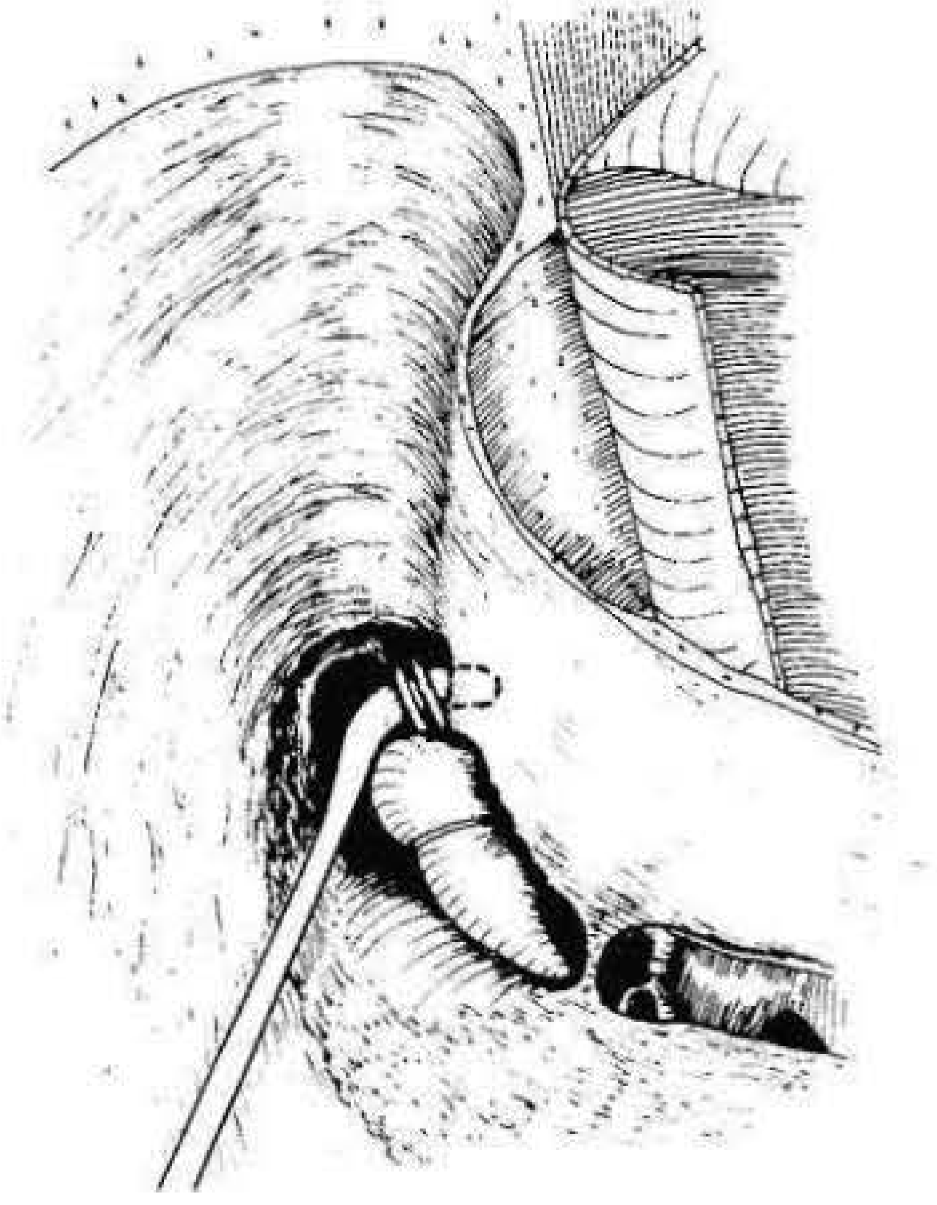


Fig. **313** A curved instrument is placed toward the Eustachian tube, indicating a good connection between the attic and the tube

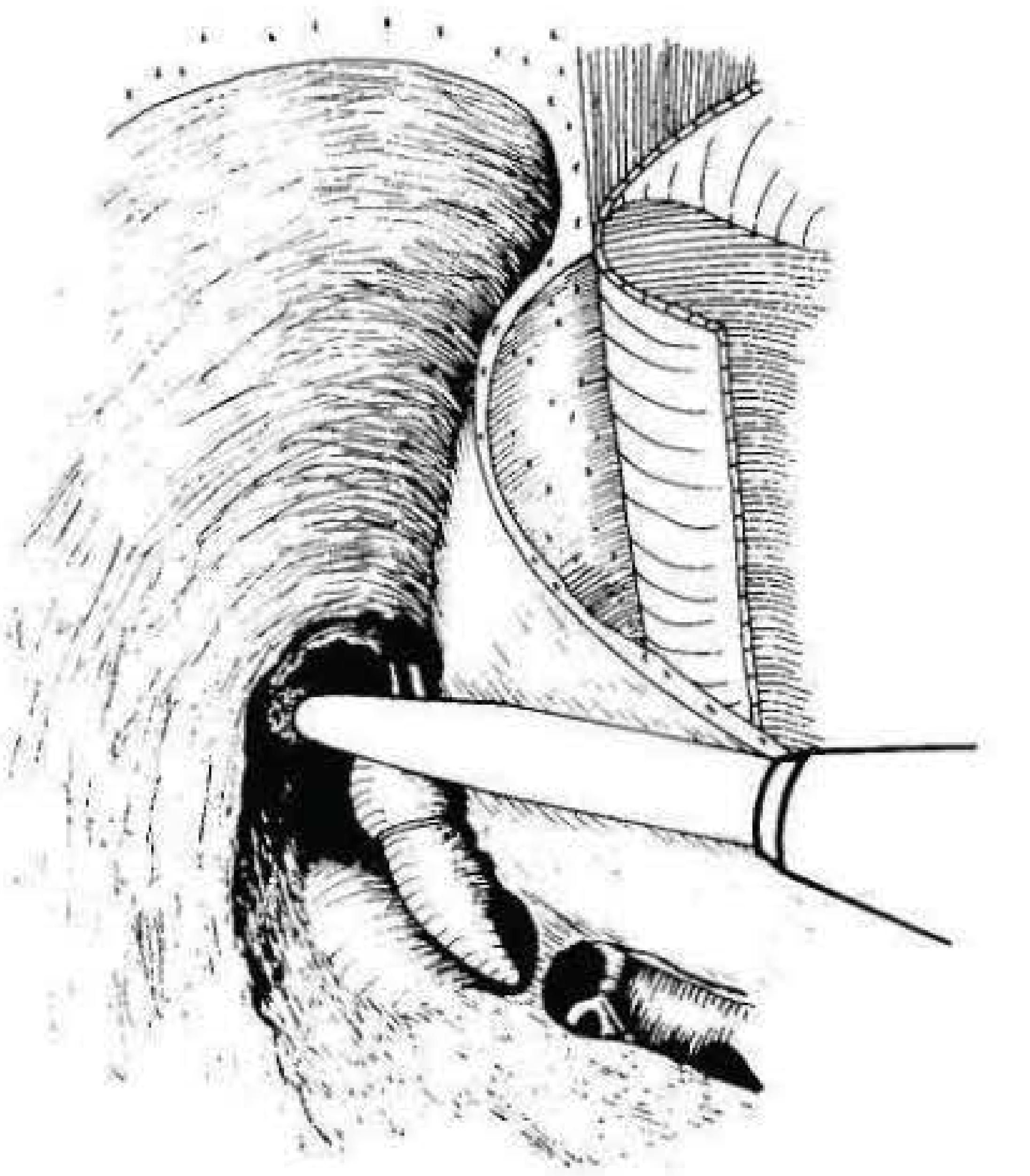


Fig. **314** Further polishing of the superior and anterior attic wall in order to remove all bony overhangs and widen the attic

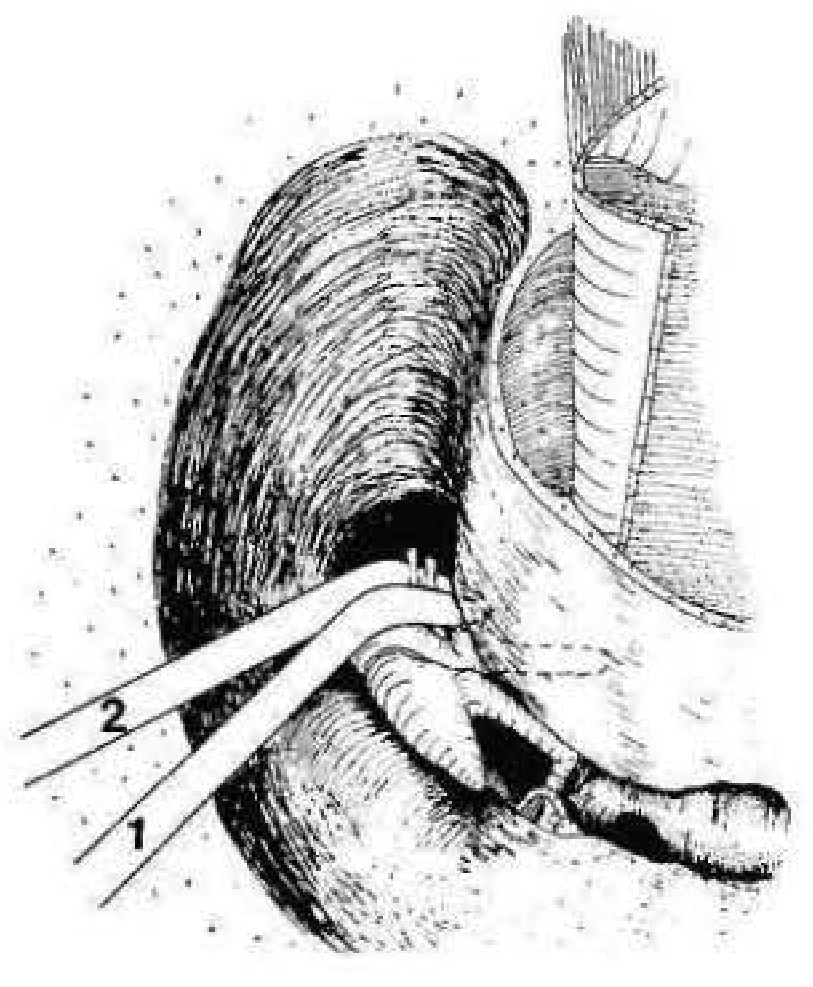


Fig. **315** **Extended anterior atticotympanotomy** by extensive thinning of the anterior meatal wall, allowing good access to the anterior tympanum between the malleolar ligament and the bony wall (1), and, after removal of the cog, good access from the anterior attic to the epitympanic sinus and the Eustachian tube. This allows a rougine to pass under the chorda tympani into the orifice of the Eustachian tube

Transmeatal Anterior Atticotympanotomy (Morimitsu)

Recognizing the importance of ventilation of the cavity through the anterior attic and the difficulties in removing cholesteatoma by the transmastoid route from the anterior attic as well as the difficulty in creating in broad connection between the attic, the epitympanic sinus, and the Eustachian tube, Morimitsu (1989, 1991) introduced a transmeatal opening of the attic in classic intact canal wall mastoidectomy. He called this procedure *anterior tympanotomy.* The present author prefers the term *anterior atticotympanotomy* to avoid confusion with the procedure of elevating an anterior tympanomeatal flap (Volume 1, Figs. **206–212**). The goal of the procedure is to enter into the anterior tympanum from the anterior attic. The term *anterior atticotympanotomy,* as already used by Farrior (1968, 1969), therefore precisely describes the procedure.

In classic intact canal wall mastoidectomy, Morimitsu (1991) performs a superior and an anterior tympanotomy by elevating a large anterosuperior tympanomeatal flap, providing a good view into the mesotympanum and anterior tympanum (Fig. **316**). In the anterior tympanum, the tensor tympani fold is located between the tensor tympani tendon and the bony plate separating the epitympanic

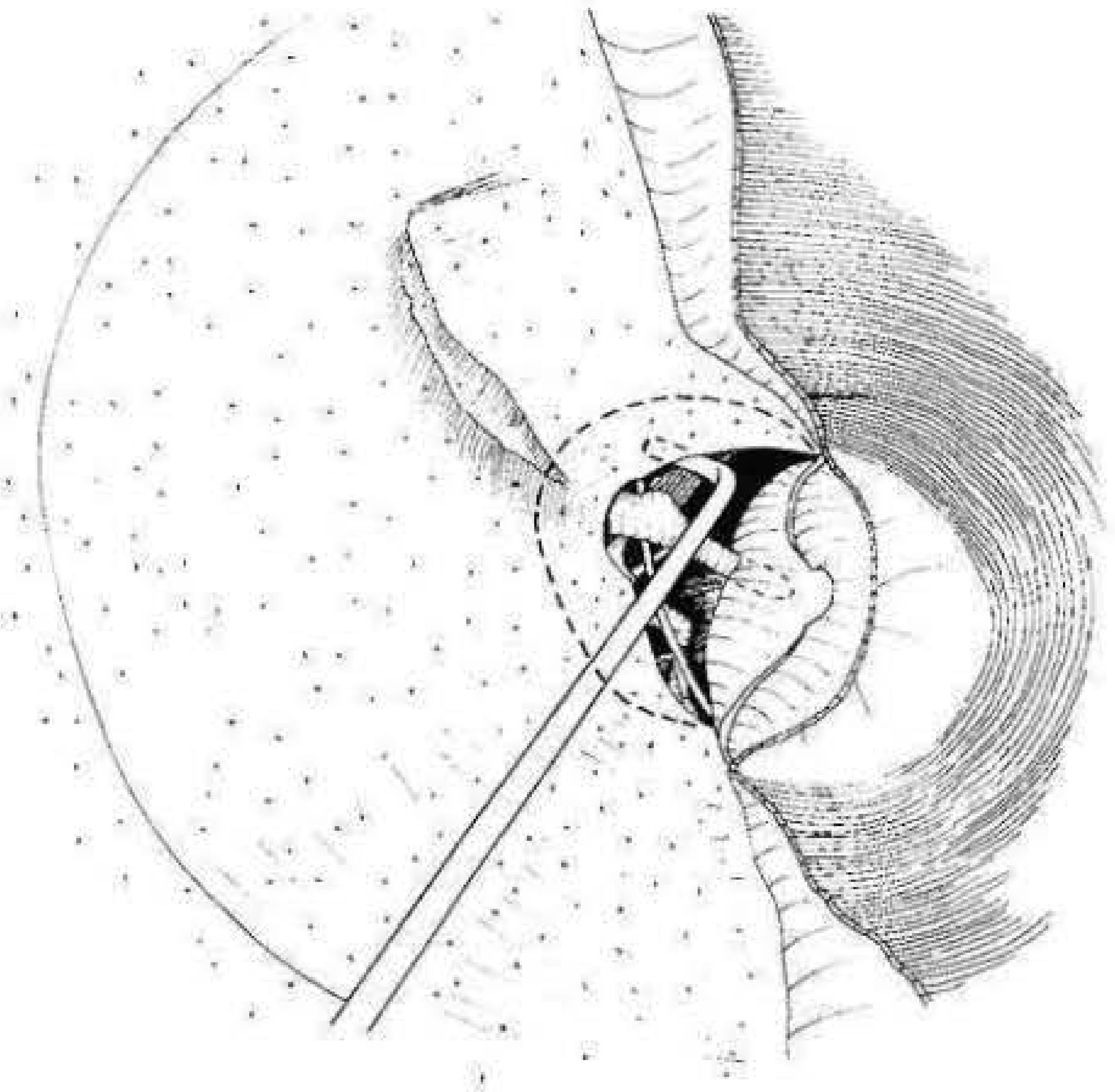


Fig. **316** **Transmeatal anterior atticotympanotomy (Morimitsu),** in connection with classic intact canal wall mastoidectomy. A large superoanterior tympanomeatal flap is elevated, providing a good view of the mesotympanum. With a curved rougine, the tensor tympani fold is torn, and the anterior attic is entered transtympanally. The dashed line indicates the border for removal of the lateral attic wall

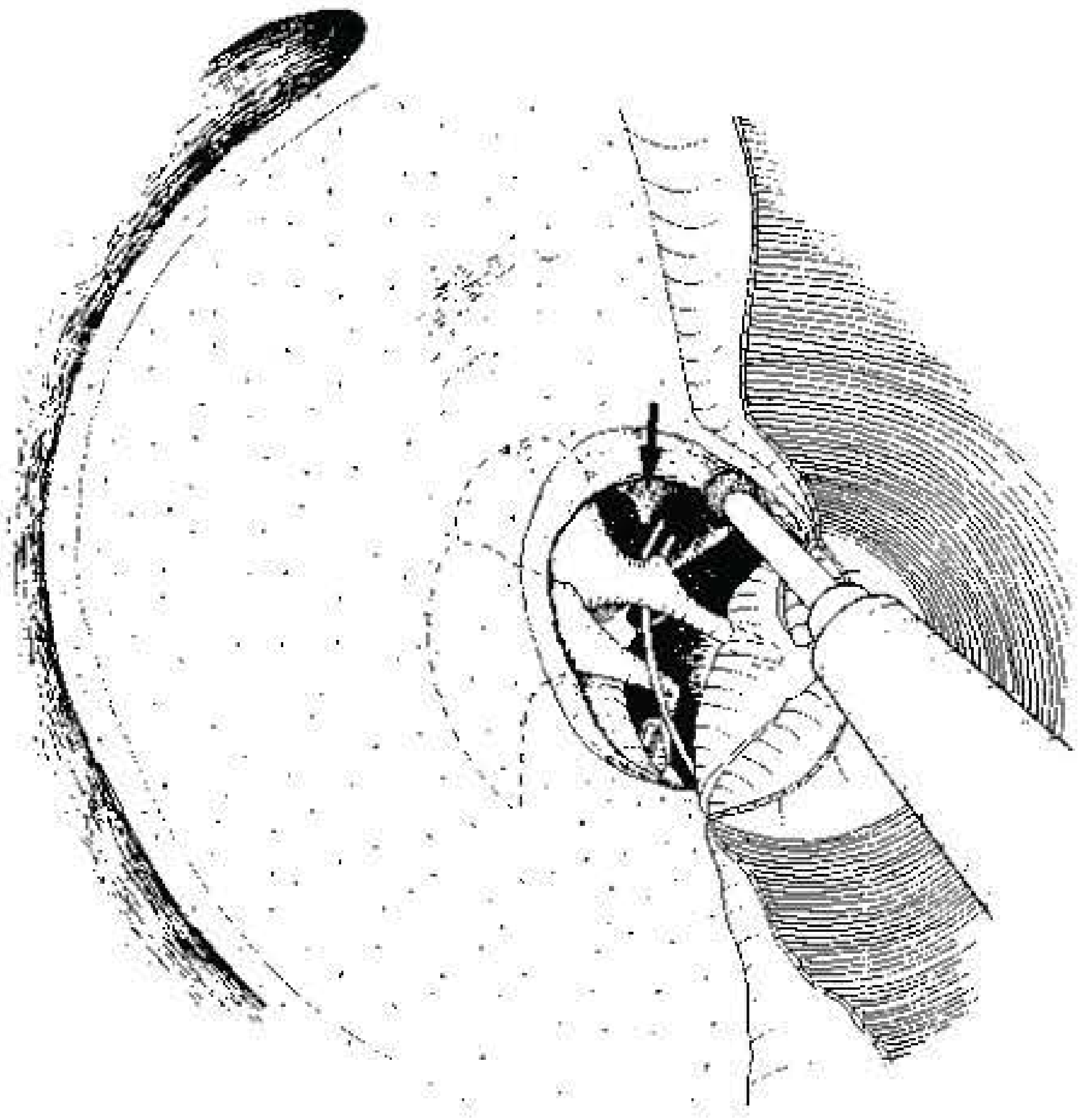


Fig. **317** The lateral attic wall has been removed, providing a good view into the anterior attic with the anterior attic bony plate or "cog" (arrow)

sinus and the Eustachian tube (Figs. **85–87**). With an angled rougine (Fig. **316**), the tensor tympani fold is removed, allowing access to the anterior tympanum.

Using a diamond burr, 2 mm of the lateral attic wall is removed, starting posteriorly the at 9-o'clock position and continuing over the Shrapnell's membrane region, proceeding anteriorly to the 2-o'clock position (Fig. **317**). In this way, the mesotympanum, parts of the incus body and malleus head, as well as the anterior attic, are exposed. In the anterior tympanum, both the eminence of the tensor tympani muscle and the orifice of the Eustachian tube are visible. After removing the tensor tympani fold, the connection between the mesotympanum and the anterior attic is established beneath the anterior malleolar fold and the chorda tympani.

After transmeatal anterior atticotympanotomy, the anterior bony plate (Morimitsu et al. 1989) or cog (Yamasoba et al. 1990), defined as the anterior border between the attic and the epitympanic sinus, is visible, and it can be removed by transmeatal drilling with a diamond burr (Fig. **318**). The drilling has to be extended far anteriorly toward the Eustachian tube (Fig. **319**). With transmeatal drilling, the chorda tympani and ossicles can easily be visualized, and the epitympanic sinus can be widely opened. Further drilling can be performed transmastoidally (Fig. **319**). When transmeatal anterior atticotympanotomy is completed, a wide access has been created between the chorda tympani and the medial wall of the anterior attic, and all the bony

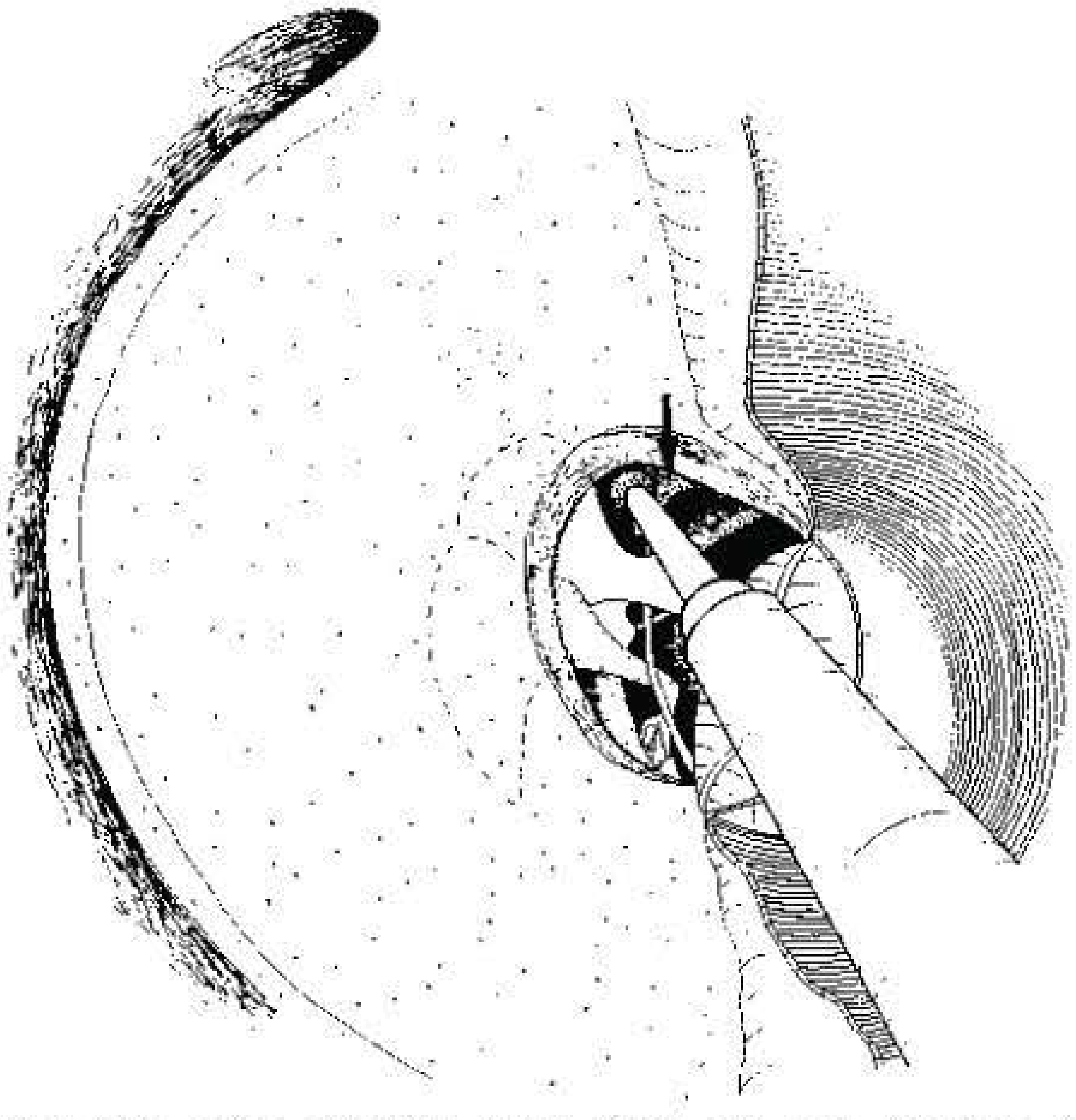


Fig. **318** The anterior bony plate or cog (arrow) is drilled away, enlarging the anterior attic and opening the epitympanic sinus

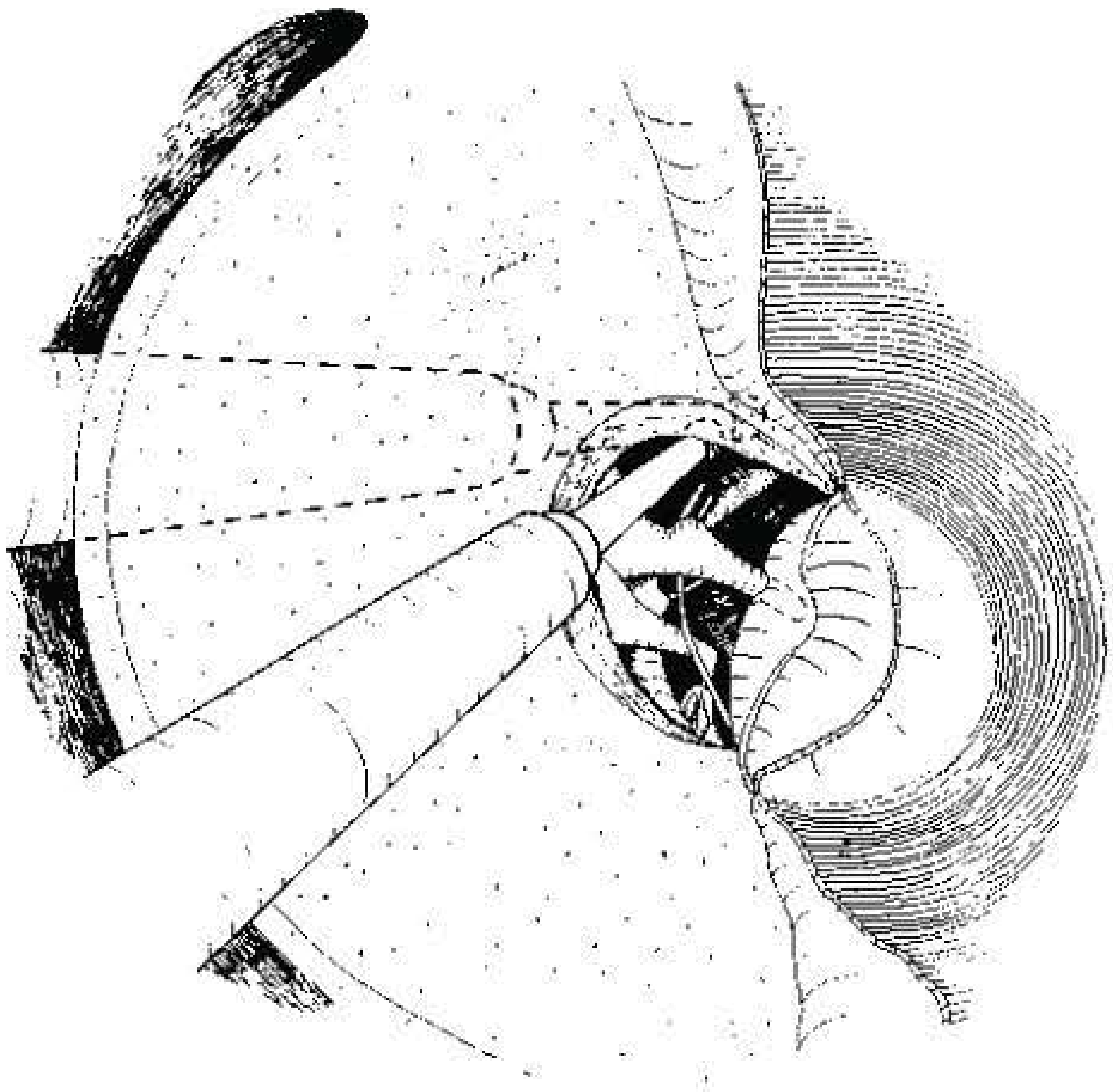


Fig. **319** **Transmeatal access and transmastoid access** (dashed burr) to the epitympanic sinus and supratubal recess spicules from the attic are removed, as is the anterior bony plate, and the connection to the Eustachian tube is widely opened (Fig. **320**). Morimitsu et al. (1989) consider this step in the classic intact canal wall mastoidectomy as the best method of preventing recurrence. The atticotomy is usually not covered by any tissue other than fascia at closure.

Some surgeons (Morimitsu et al. 1989, Yamasoba et al. 1990) believe that the anterior bony plate is a congenital formation, and represents a causative factor in attic cholesteatoma. Others, including the present author, believe that the narrow space in the attic leading to a thick anterior bony plate is a consequence of poor pneumatization, as is the low position of the dura and the sclerotic mastoid process. Some surgeons (Rosborg 1993) perform a more extensive transmeatal atticotympanotomy in intact canal wall mastoidectomy, in order to remove cholesteatoma from the attic and widen the connection to the Eustachian tube (Fig. **321**). In such cases, the atticotomy needs to be covered by a piece of cortical bone or cartilage.

Sometimes extensive removal of the bony ear canal is performed (Fig. **322**), but this method can hardly be classified as classic intact wall mastoidectomy.

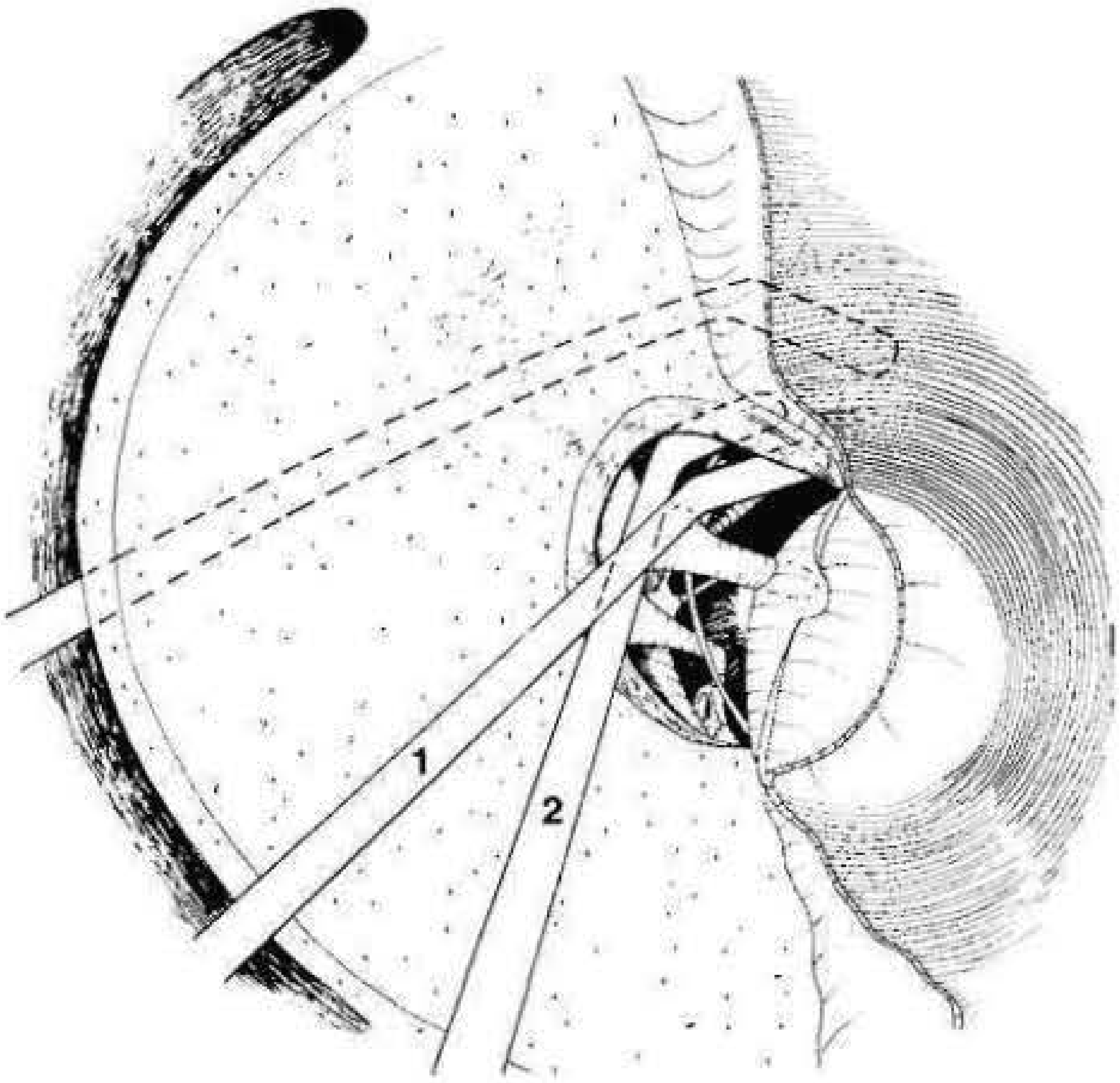


Fig. **320** With a curved elevator, the anterior tympanum is entered transmeatally (1), lateral and (2) medial to the chorda tympani. The transmastoid passage through the epitympanic sinus is indicated by the dashed rougine

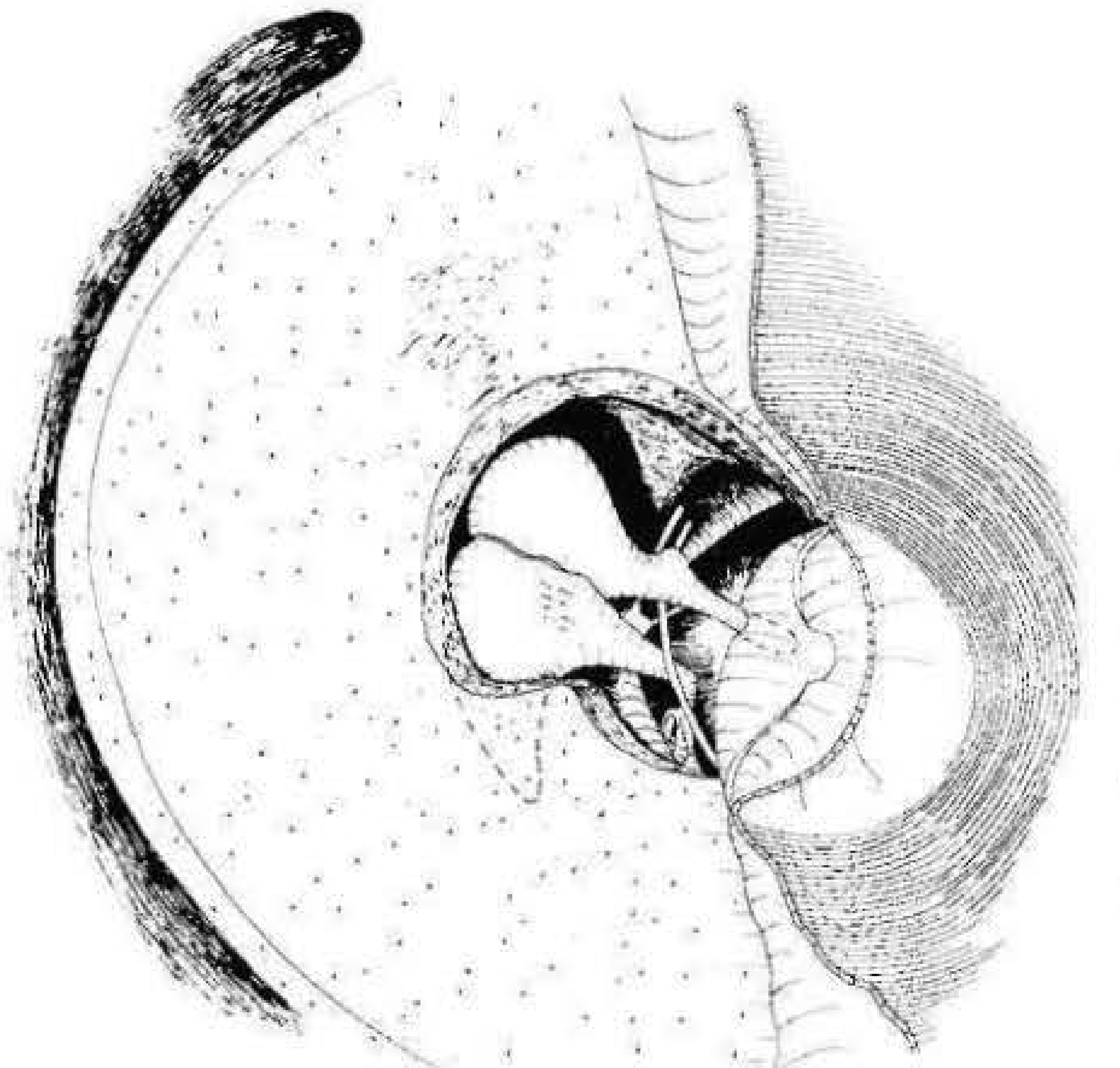


Fig. **321** **Extensive transmeatal anterior atticotympanotomy (Rosborg)**. After removal of the lateral attic wall, the atticotomy and transmeatal anterior atticotympanotomy are performed

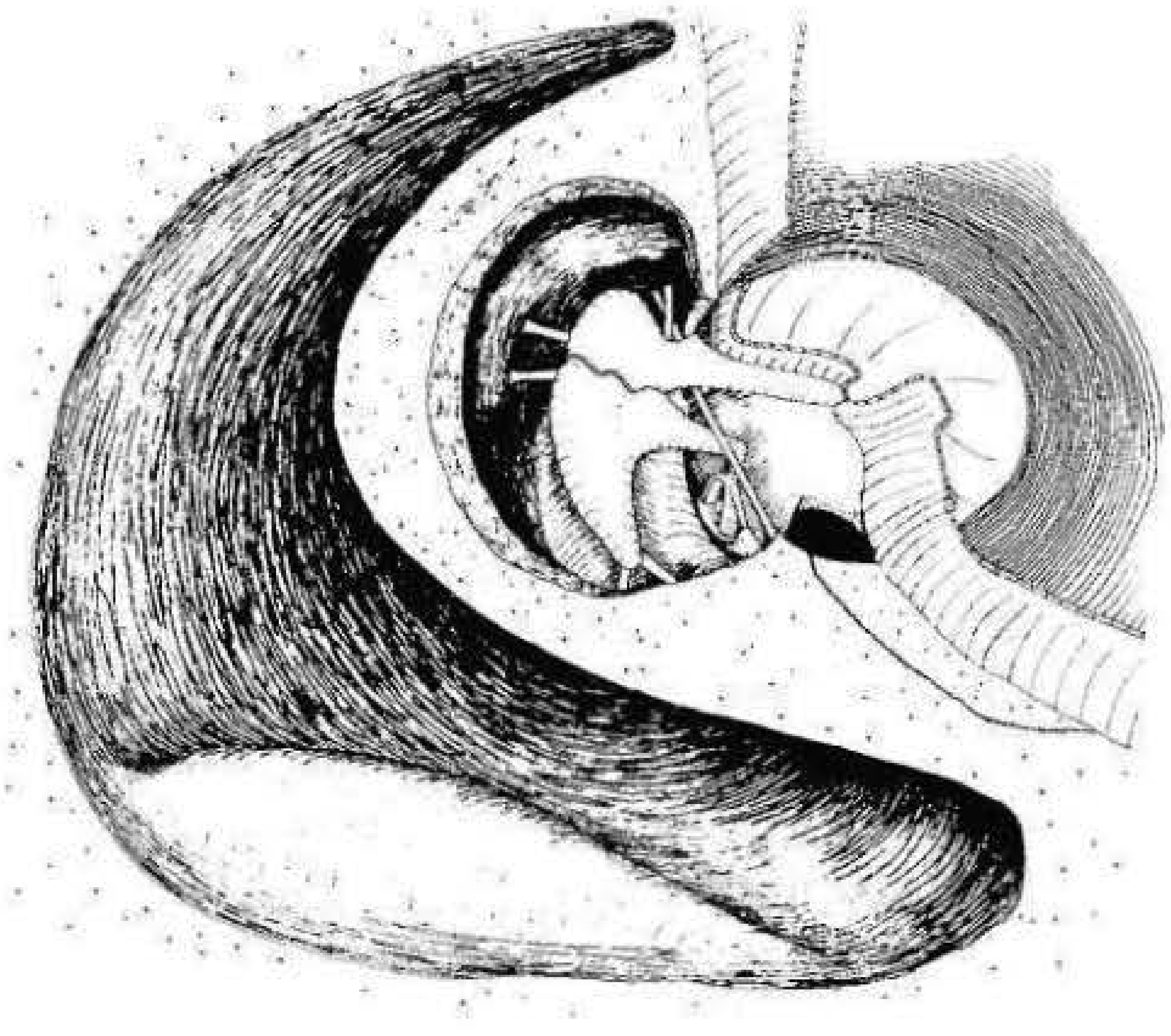


Fig. **322** **Extensive removal of the lateral attic wall** in intact canal wall mastoidectomy

Removal of Cholesteatoma

The goal of the surgery is to remove the cholesteatoma completely without risk of residual cholesteatoma. This can be achieved in various ways. Some surgeons, e. g. Marquet (1989), recommend radical surgery, and remove all structures in contact with the cholesteatoma, almost as in cancer surgery. Other surgeons, including the author, are more conservative, and dissect the cholesteatoma away from the drum remnant and ossicles in order to preserve them.

Marquet recommends the following strict rules in the eradication of cholesteatoma:

- Any ear suspected of cholesteatoma should be approached retroauricularly, and the extent of the sac should be assessed from behind. He recommends a large retroauricular combined-approach mastoidectomy, allowing visualization of the whole middle ear cavity, in order to allow total removal of the pathology, whatever its nature and location. The whole mastoid from the front of the attic to the tip, as well as the middle ear cleft, should be opened at the same time, and only when the shape and size of the cholesteatoma and its extent are perfectly visualized should removal be started.
- The removal of the pathology should always be performed from the mastoid and the attic toward the external ear canal. The natural pathway along which the cholesteatoma develops in the middle ear cleft should be treated in the *reverse direction,* depending on the location of the entrance through the tympanic membrane defect. The cholesteatoma sac, the drum remnant including the fibrous annulus, the connections between these structures and the matrix, and all the pathology, should always be elevated laterally together with the meatal skin and removed (Fig. **323**).
- The cholesteatoma should be pushed in toto out of the mastoid process and antrum and into the ear canal using artificial sponge bullets and a bowl-shaped elevator (Fig. **324**).

Marquet's (1989) concept of cholesteatoma removal along with the drum remnant, fibrous annulus, and malleus was established in order to use allograft drum in reconstruction. Today, very few surgeons use allogeneic drum and (Magnan and Bremond 1985, Ars 1993), and the number is decreasing because of the risk of AIDS as well as the risk of Creutzfeldt-Jakob disease.

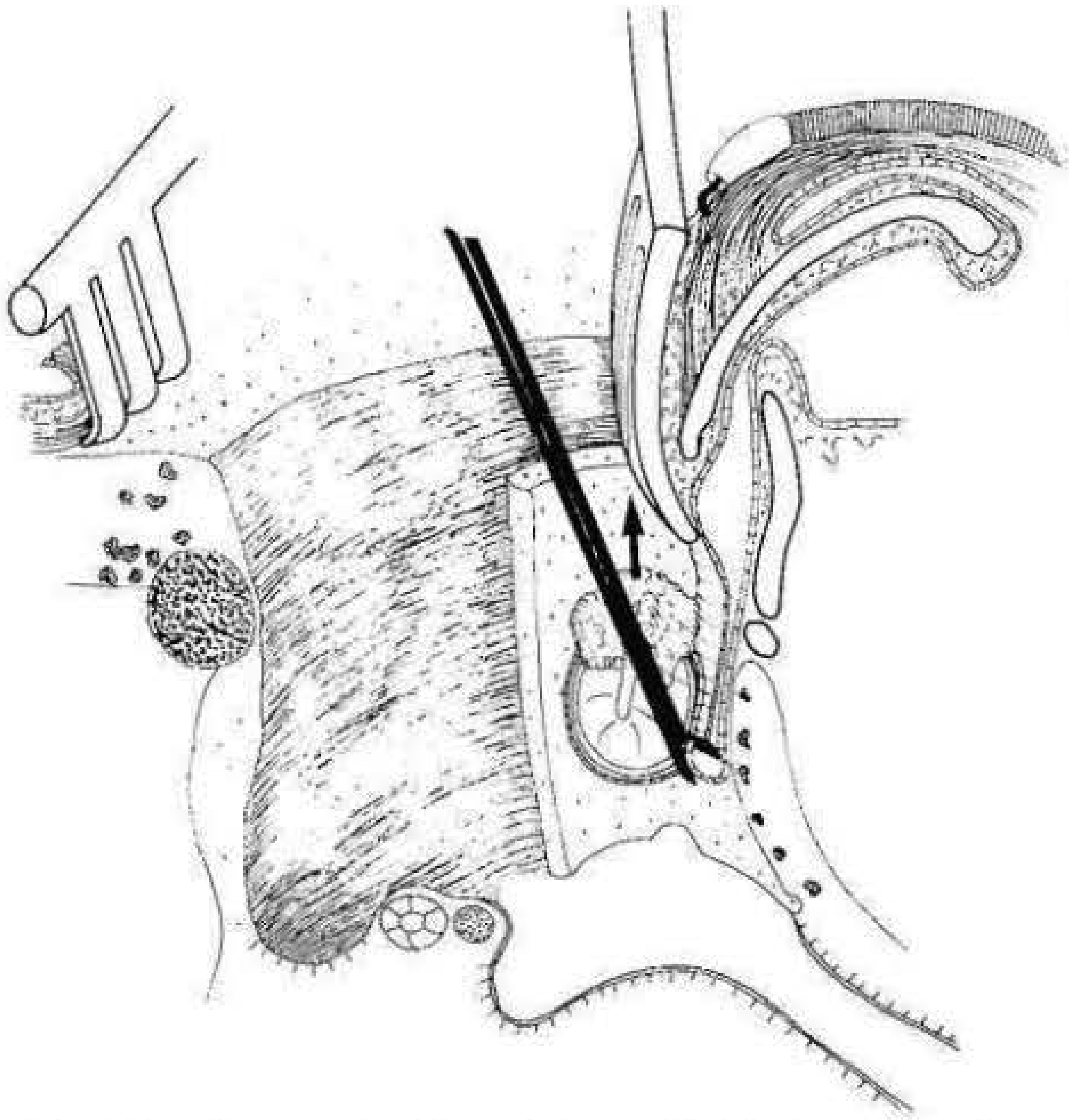


Fig. **323** **Removal of an attic cholesteatoma in classic intact canal wall mastoidectomy** together with the drum, fibrous annulus, and malleus, as indicated by Marquet, in order to replace the drum with an ailogenous drum. The last ear canal skin attachment of the drum is cut, and the attic cholesteatoma with the malleus and the drum is pulled out of the ear canal (arrow)

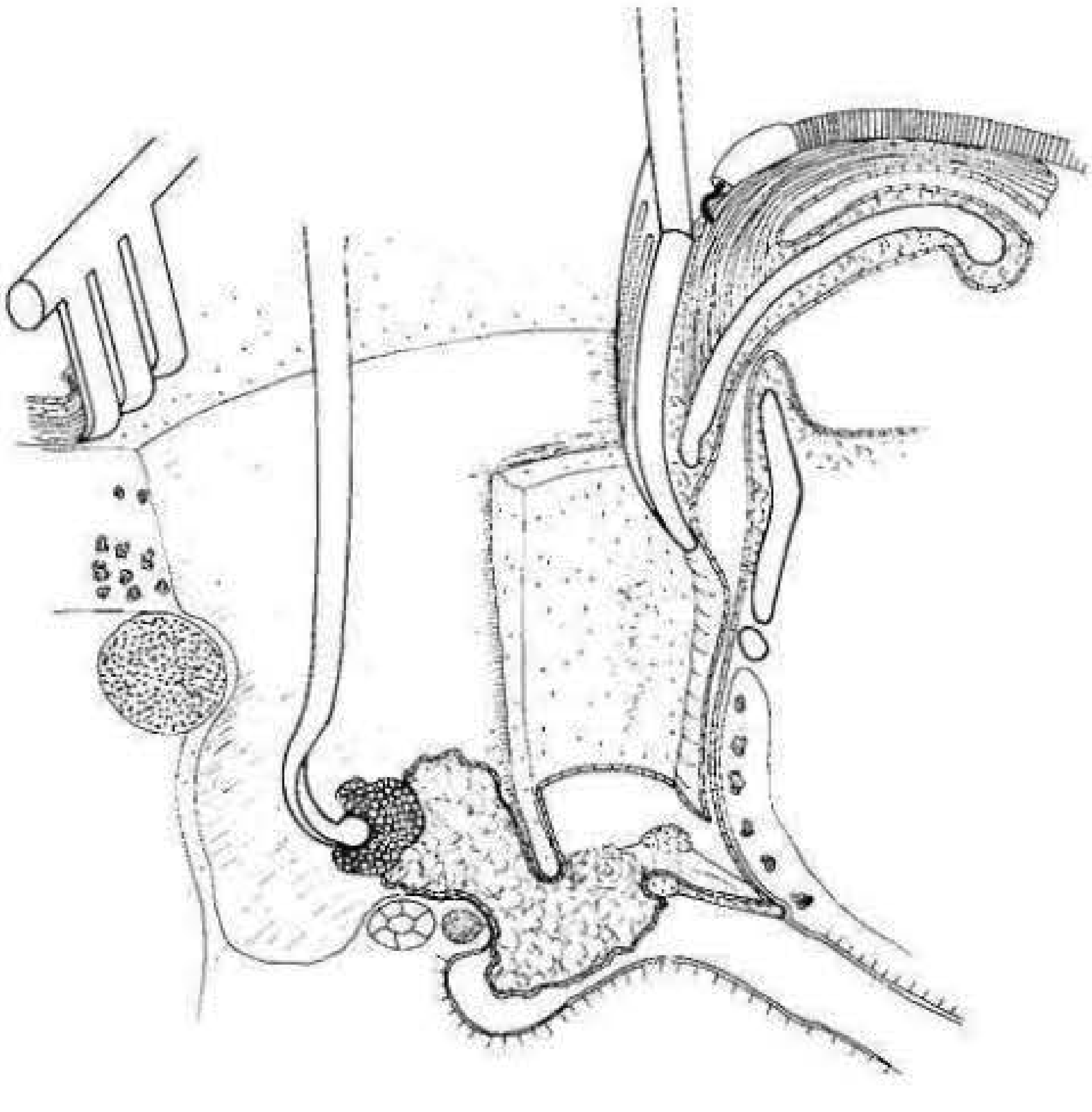


Fig. **324** **Removal of an attic cholesteatoma in classic intact canal wall mastoidectomy** by pushing an intact sac with a bowl-shaped elevator and artificial sponge bullets under the intact ear canal wall into the tympanic cavity and ear canal (Marquet)

Conservative Cholesteatoma Removal

The majority of surgeons elevate the cholesteatoma membrane from its surroundings, and leave the other structures intact. The present author has never followed the Marquet concept of cholesteatoma removal, and it is difficult to undestand why the pars tensa should be removed in cases of attic cholesteatoma when no cholesteatoma is present in the tympanic cavity. It is also difficult to understand why the anterior part of the drum, including the malleus, should be removed in a sinus cholesteatoma with pathology restricted to the posterior tympanum.

The various types of cholesteatoma—the attic, sinus, and tensa retraction cholesteatomas—each has its own specific situation, involving the extent and pathology, and each type should be removed in a different way, with the approach, route, and mastoidectomy type always being taken into consideration.

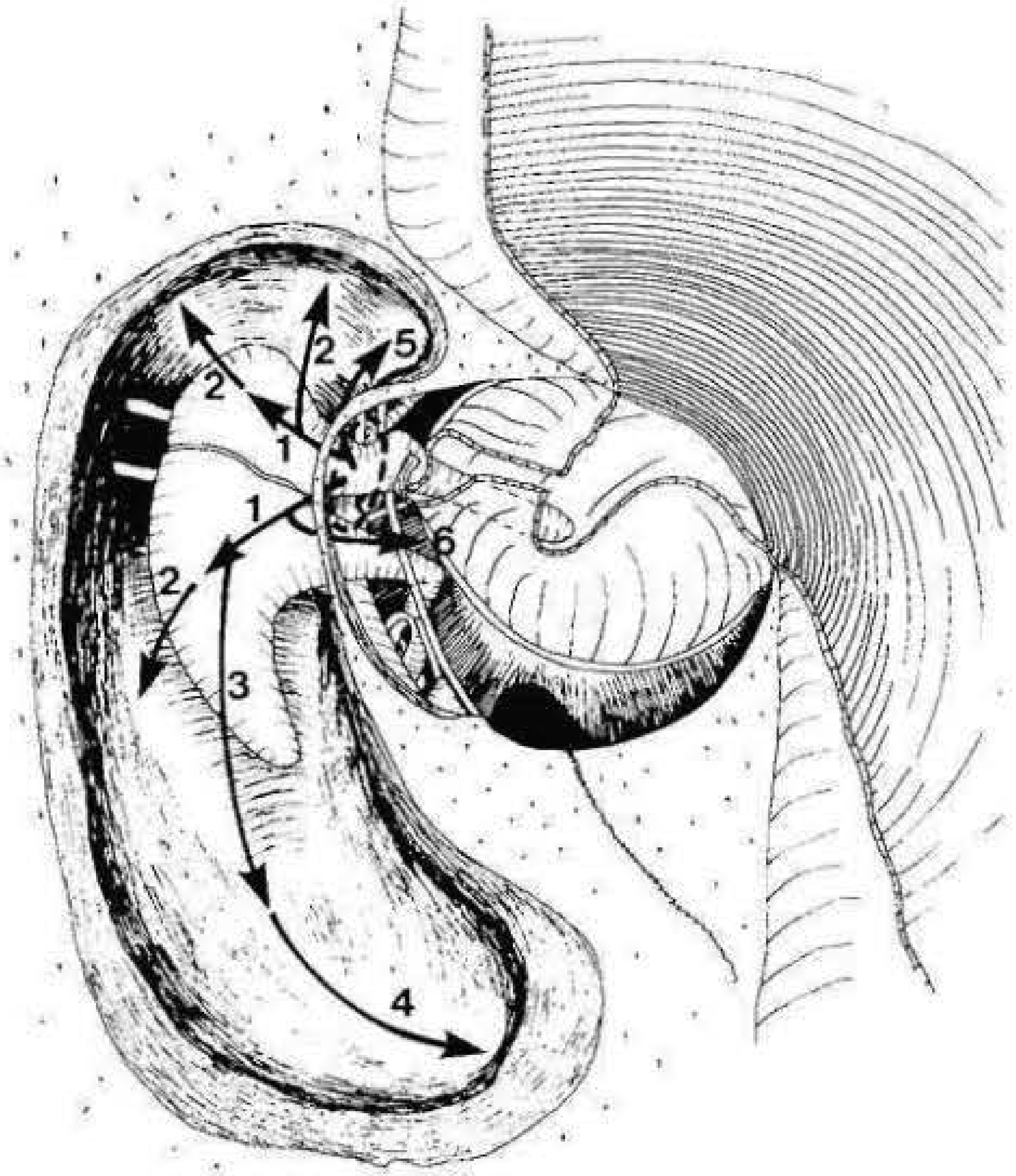


Fig. **325** **Lateral extension of attic cholesteatoma** explained in an atticoantrotomy situation with preserved bridge. From the Shrapnell's membrane region (dashed), the cholesteatoma membrane extends laterally on the incus body and malleus head (1), then up to the anterior, superior, and posterior attic (2), from there to the aditus ad antrum and antrum (3), and into the mastoid process (4). Some rare cholesteatomas extend anteriorly direct into Prussak's space (5), or along the malleus neck into the tympanic cavity (6)

Removal of Attic Cholesteatoma

Attic cholesteatoma manifests itself as a retraction of Shrapnell's membrane and extends into the lateral attic, where it is attached lateral to the malleus head and the incus body. From the lateral attic, it extends to the anterior, superior, and posterior attic, and from there to the antrum and eventually to the mastoid process (Fig. **325**). The cholesteatoma can in some cases be elevated from the malleus head and incus body, preserving the ossicular chain intact.

In many cases, the cholesteatoma extends from the superior attic as a retraction around the malleus head and incus body into the medial attic, sometimes protruding into the tympanic cavity at the eminence of the horizontal part of the facial nerve. This extension passes through the tympanic isthmus (Fig. **326**). When the cholesteatoma extends medially, it is difficult to save the incus body, but the malleus head can often be cleared of cholesteatoma membrane and left in place, to avoid an empty attic.

From the anterior attic, a medial extension passes around the malleus head and down to the tensor tympani fold, where it may stop, or sometimes continue into the epitympanic sinus (Fig. **327**). In medial extension of attic cholesteatoma, the sac consists of four cholesteatoma membranes: the most

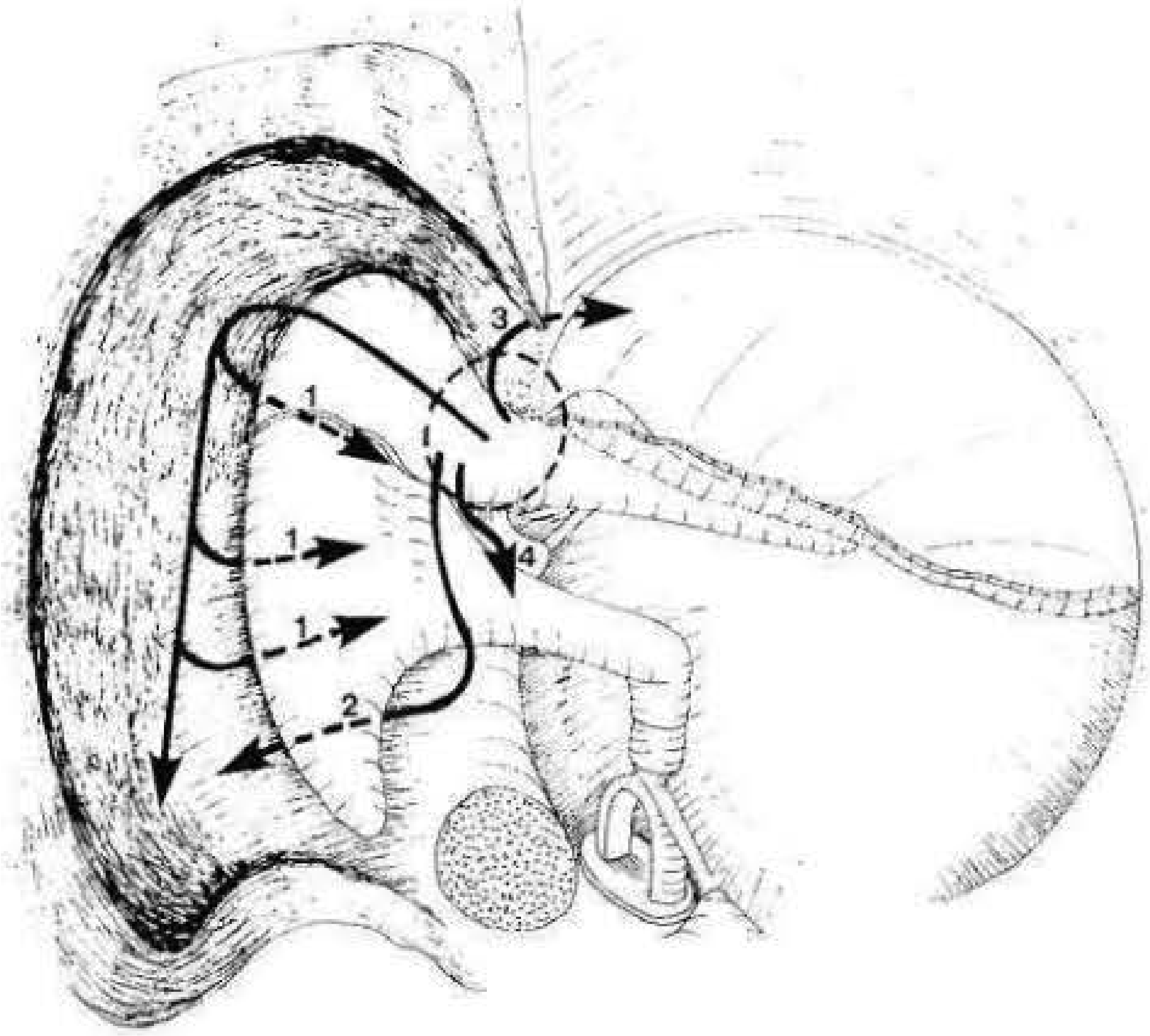


Fig. **326** **Medial extension of attic cholesteatoma** around the superior aspect of the malleus head and incus body, as a retraction into the medial attic (1); from Shrapnell's membrane along the incus body, and medial to the short process of the incus, continuing into the attic (2); from the Shrapnell's membrane and Prussak's space under the anterior malleolar fold into the anterior part of the tympanic cavity (3); and from Shrapnell's membrane between the malleus neck and the long process of the incus into the mesotympanum (4)

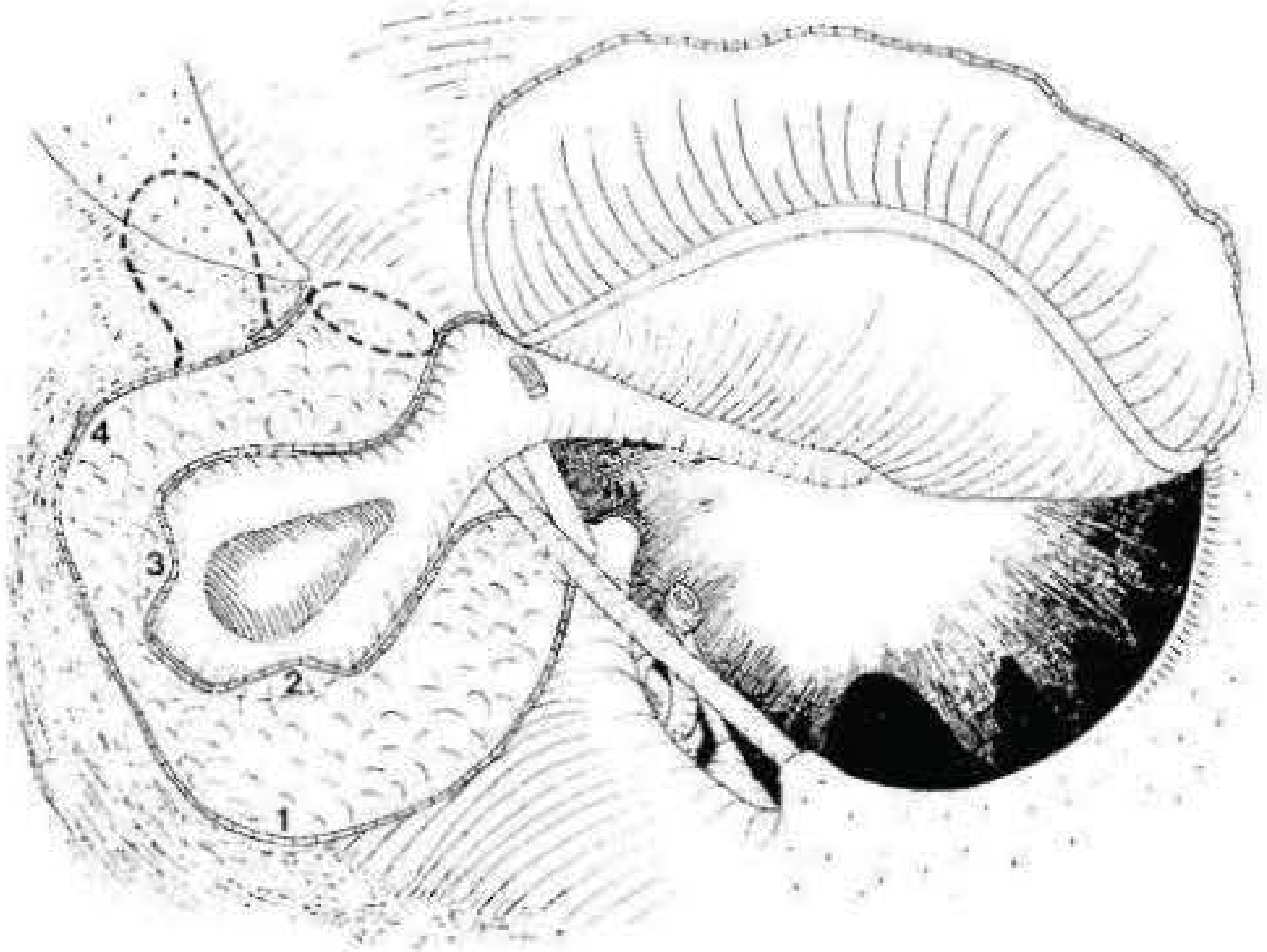


Fig. **327** **Extension of attic cholesteatoma in the anterior attic.** From Shrapnell's membrane (dashed) along the lateral and superior attic medially to the malleus head, and from there possibly to the epitympanic sinus (dashed). Attic cholesteatoma can have four basic membranes: one attached to the medial wall of the attic (1), one to the medial aspect of the malleus head, resorbing it (2), one attached to the lateral aspect of the malleus head, resorbing it (3), and one attached to the lateral wall of the attic (4)

medial one, lying on the medial wall of the attic and on the lateral semicircular canal; one lying on the medial and one on the lateral surface of the incus body and malleus head; and the most lateral membrane, covering the lateral wall of the attic. In such cases, the ossicles are usually resorbed, and their preservation is impossible. The incus usually has no contact with the stapes. In these cases, the malleus head is resected, resulting in an empty attic with a high risk of retraction.

In classic intact canal wall mastoidectomy, after the lateral mastoid cells have been exenterated and Körner's septum has been opened, the cholesteatoma is elevated, which in cases with a large sac is located in the antrum. It is demarcated from the surrounding structures and opened with a sickle knife. The cholesteatoma mass is suctioned out, debulking the sac, and allowing further dissection of the cholesteatoma membrane (Fig. **328**). After debulking of the cholesteatoma and elevation of the membrane, space is gained for further drilling. The cholesteatoma membrane is elevated toward the ear canal wall (Fig. **329**) and after further drilling and thinning of the bony canal wall, the cholesteatoma membrane is elevated from the ossicles, the lateral semicircular canal, and the attic wall.

The general principles of removal of cholesteatoma from the antrum and the mastoid tegmen are described in Chapter 4 (Figs. **131, 132, 147**). Removal of cholesteatoma from the mastoid process and the antrum in cases with a prominent sigmoid sinus, and cleaning of the posterior fossa dura plate, have also been described in Chapter 4

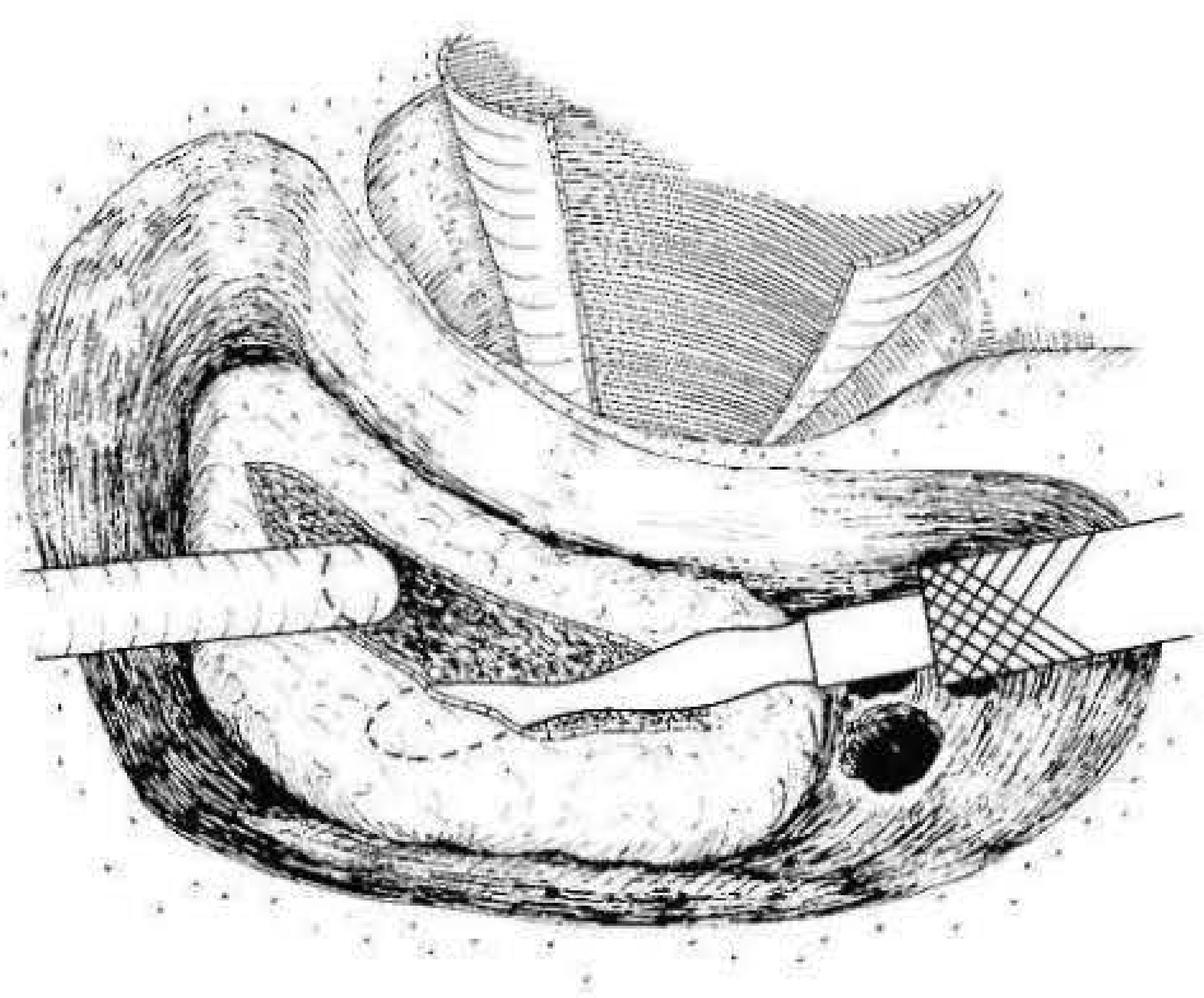


Fig. **328** **A large attic cholesteatoma in the antrum and mastoid process.** The cholesteatoma is incised and debulked by removing of the cholesteatoma mass with a broad rougine and a large suction tube

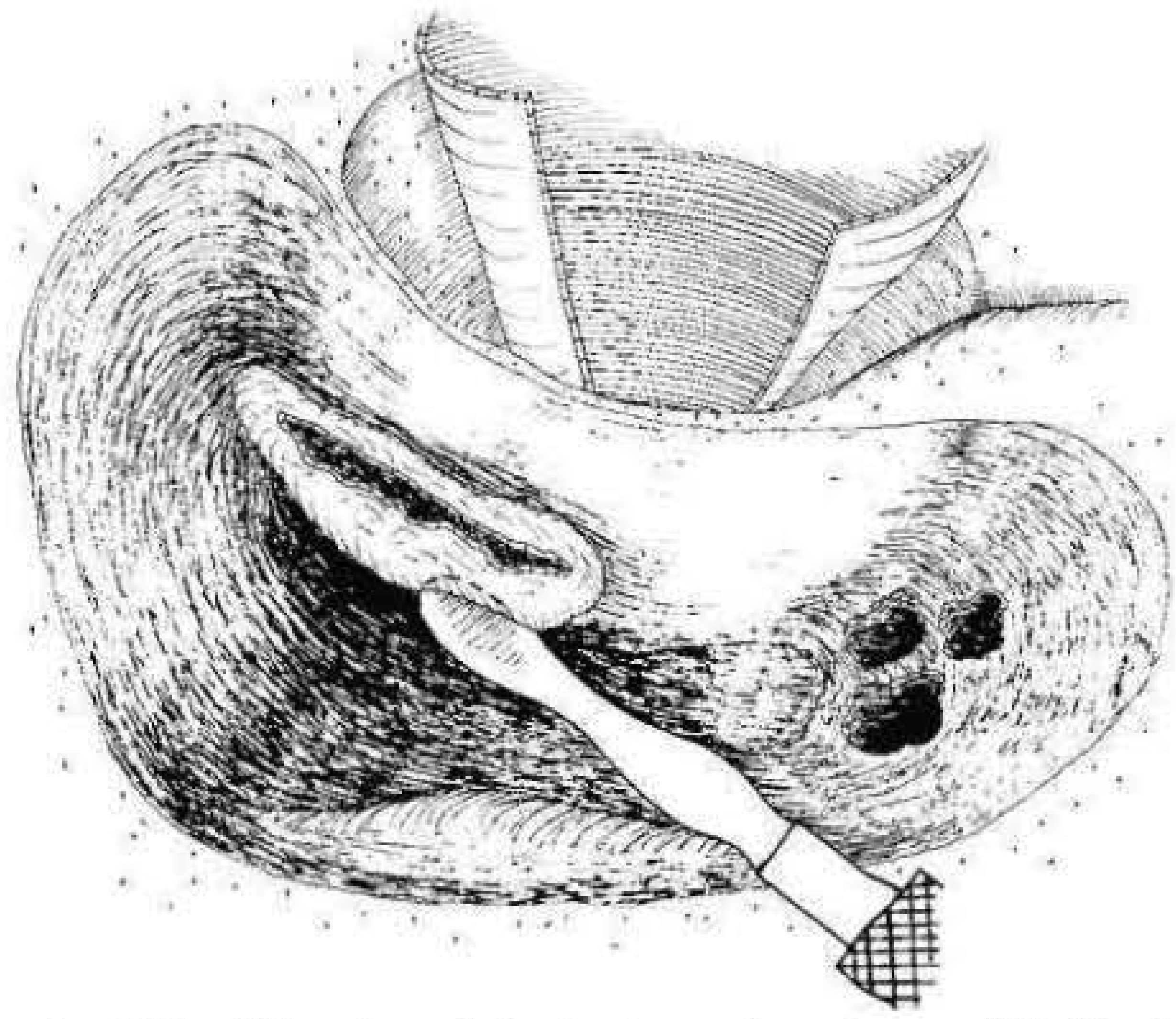


Fig. **329** After the cholesteatoma has been debulked, the membrane is elevated and gradually pushed toward the attic

(Figs. **152–155**). Removal of cholesteatoma from the perilabyrinthine space, especially the supralabyrinthine region in adults, is illustrated in Figures **186** to **188.** Problems of extension of cholesteatoma into the perilabyrinthine cells, especially in childhood cases with extensive pneumatization, and the removal of cholesteatoma from these cells, are also described in Chapter 4 (Figs. **219–239**). The specific problems associated with attic cholesteatoma extending around the ossicles will be described here.

Attic Cholesteatoma in Intact Ossicular Chain

It is the present author's opinion that an intact ossicular chain should be preserved if it is possible to remove the cholesteatoma safely. Postoperative hearing is best with an intact chain, the reconstruction is easier, and possible postoperative retractions are more easily controlled than in cases with a empty attic. The surgeon should at least make an attempt to preserve the ossicular chain intact.

After gradually thinning the ear canal wall and elevating the cholesteatoma membrane toward the lateral attic, the cholesteatoma membrane is reduced, and the cholesteatoma mass within the sac is removed so that the region of the lateral semicircular canal can be located (Fig. **330**). After palpation of the surface of the lateral semicircular canal, excluding a fistula, and after palpation of an intact incus body and malleus head, removal of the membrane from the ear canal wall takes place. The cholesteatoma membrane is elevated from the posterior surface of the ear canal wall (Fig. **331 a**) and the remaining bony overhang is drilled away with a diamond burr (Figs. **332, 331b**) before the cholesteatoma is elevated from the lateral semicircular canal (Fig. **333**). At this point, care should be taken to avoid the instrument protruding into an unexpected fistula. After the lateral semicircular canal is cleaned, the last attachment of the cholesteatoma membrane to the incus body is gradually elevated and removed (Fig. **334**). Removal of the cholesteatoma membrane from the incus body can then be performed as long as the cholesteatoma membrane does not extend too far medial to the incus body. In attic cholesteatoma with an intact ossicular chain, the sac seldom extends into the facial recess region, but after the posterior atticotympanotomy and has been performed and it is established that the ossicular chain is intact, the preserved posterior buttress can be cleaned (Fig. **335**).

In cases of extension—which is usually a fingerlike protrusion—of the cholesteatoma from the lateral attic into the tympanic cavity, along the long

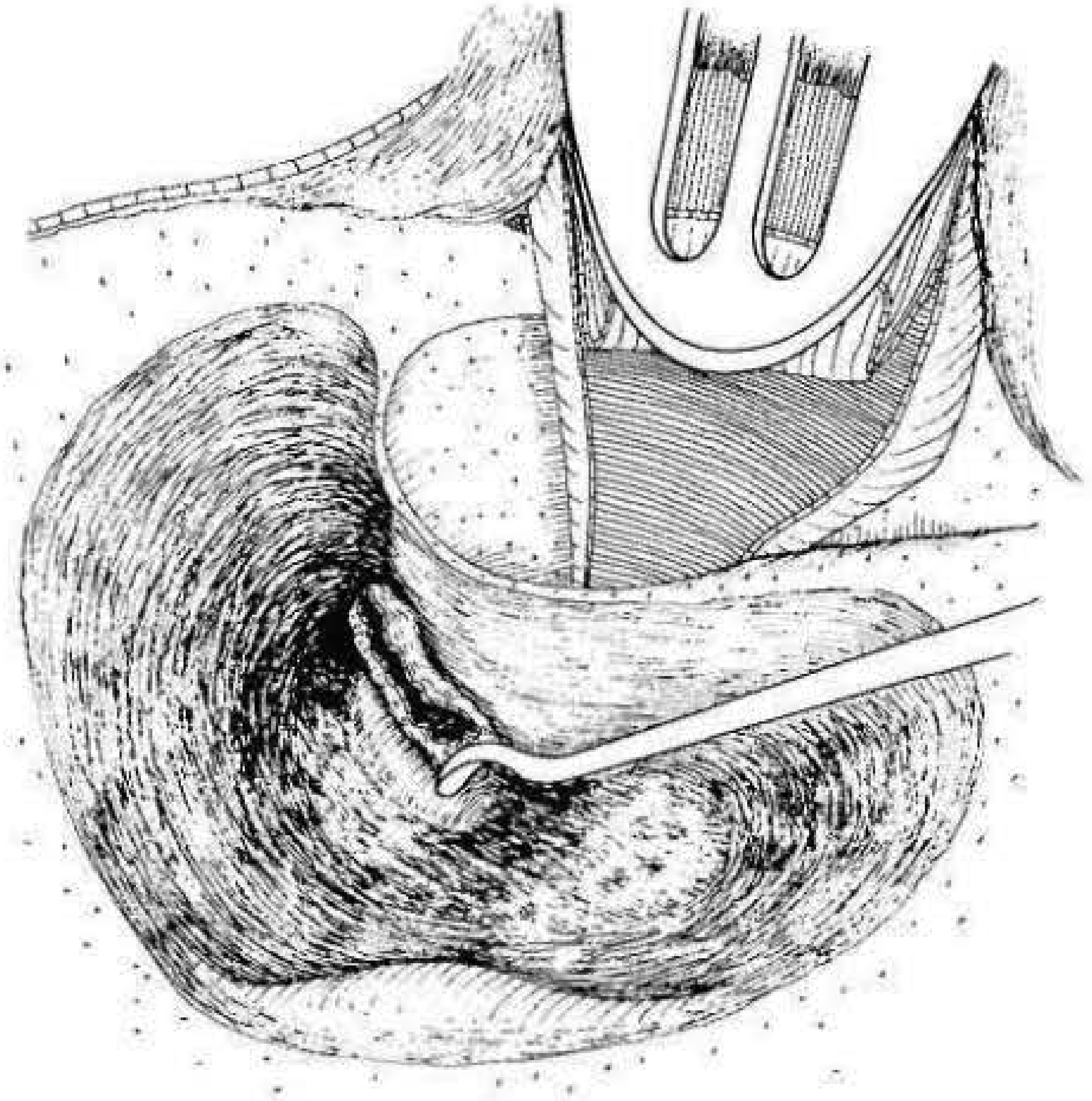


Fig. **330** The cholesteatoma membrane is gradually cut, and the last part is attached to the ossicles and the lateral semicircular canal region

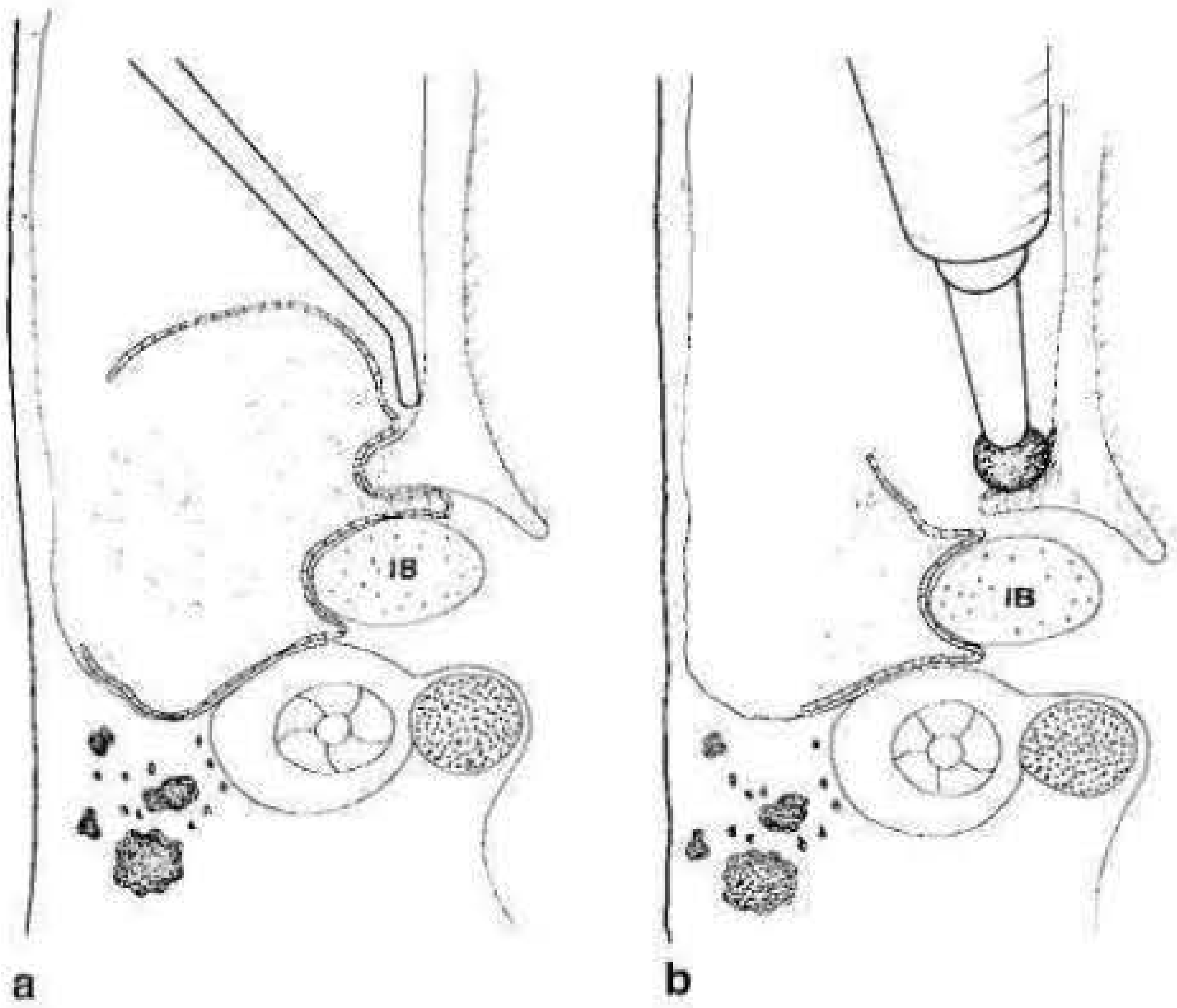


Fig. **331 a** **Side view of removal of an attic cholesteatoma at the level of the incus body** (IB)
b The cholesteatoma membrane is elevated from the posterior meatal bony wall. The meatal wall is smoothed with a diamond burr, and the cholesteatoma membrane is elevated from the lateral aspect of the incus body

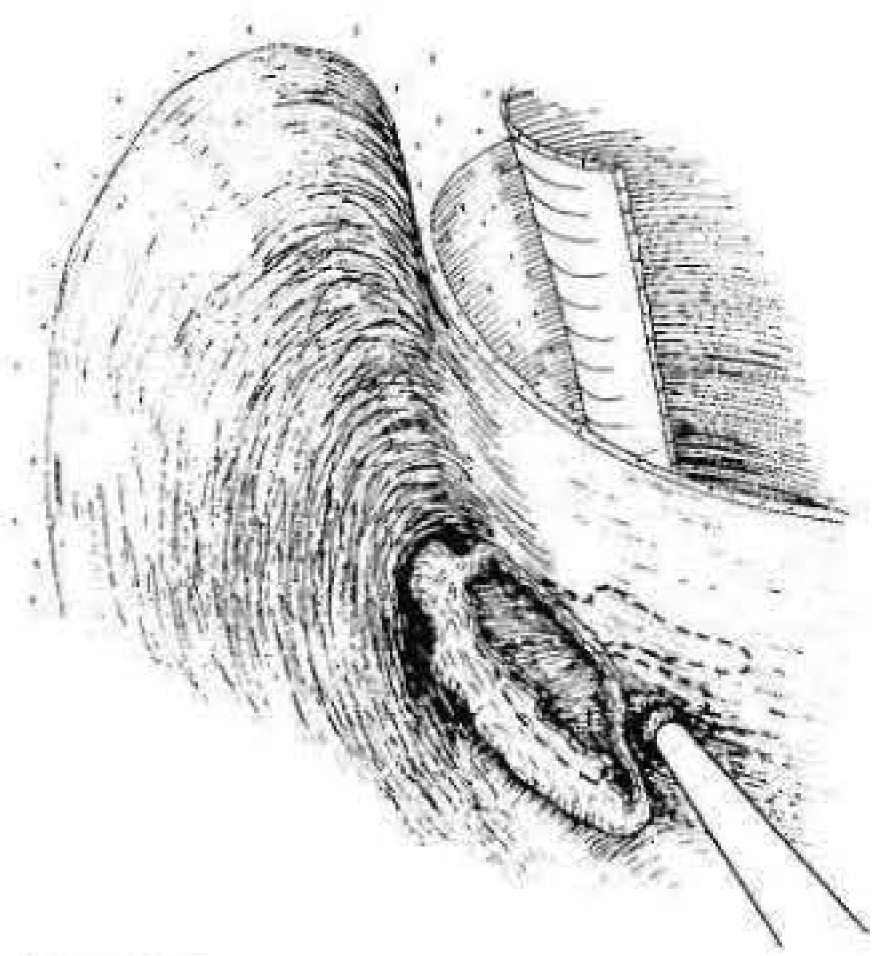


Fig. 332

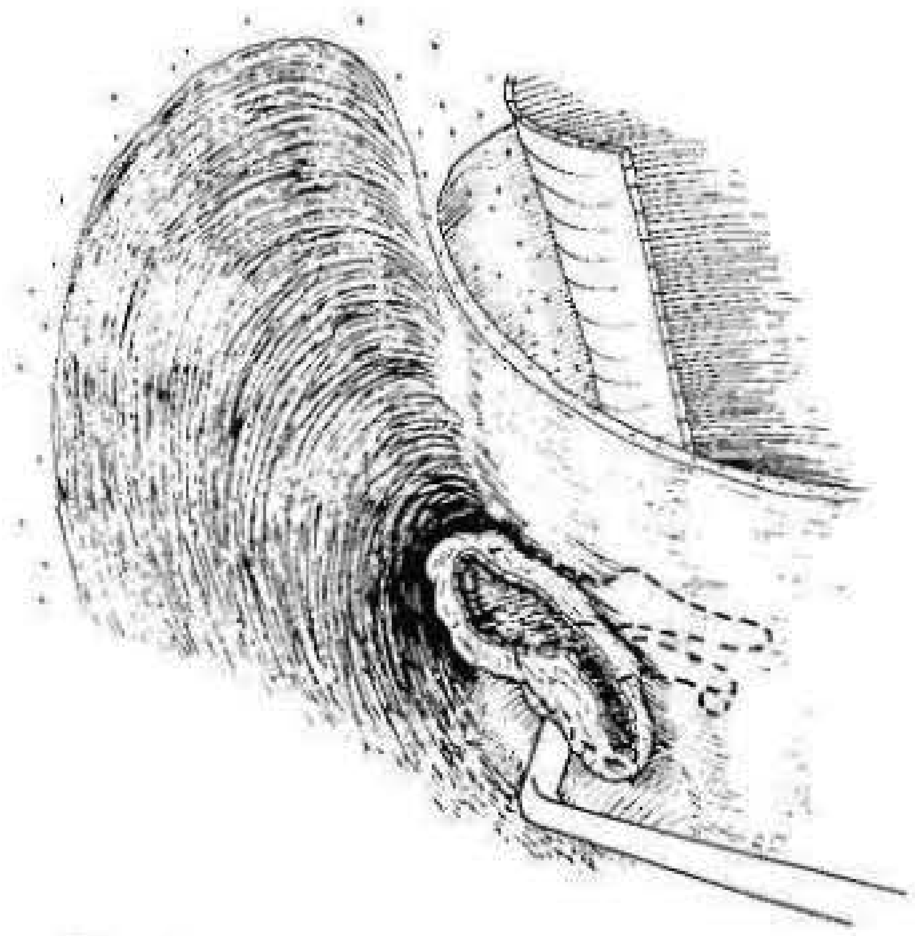


Fig. 333

Fig. 332 **Classic intact canal wall mastoidectomy,** with the remnant of the cholesteatoma membrane attached to the ossicles and the posterior ear canal wall, which is further smoothed and the cholesteatoma membrane elevated

Fig. 333 Elevation of the cholesteatoma membrane from the lateral semicircular canal

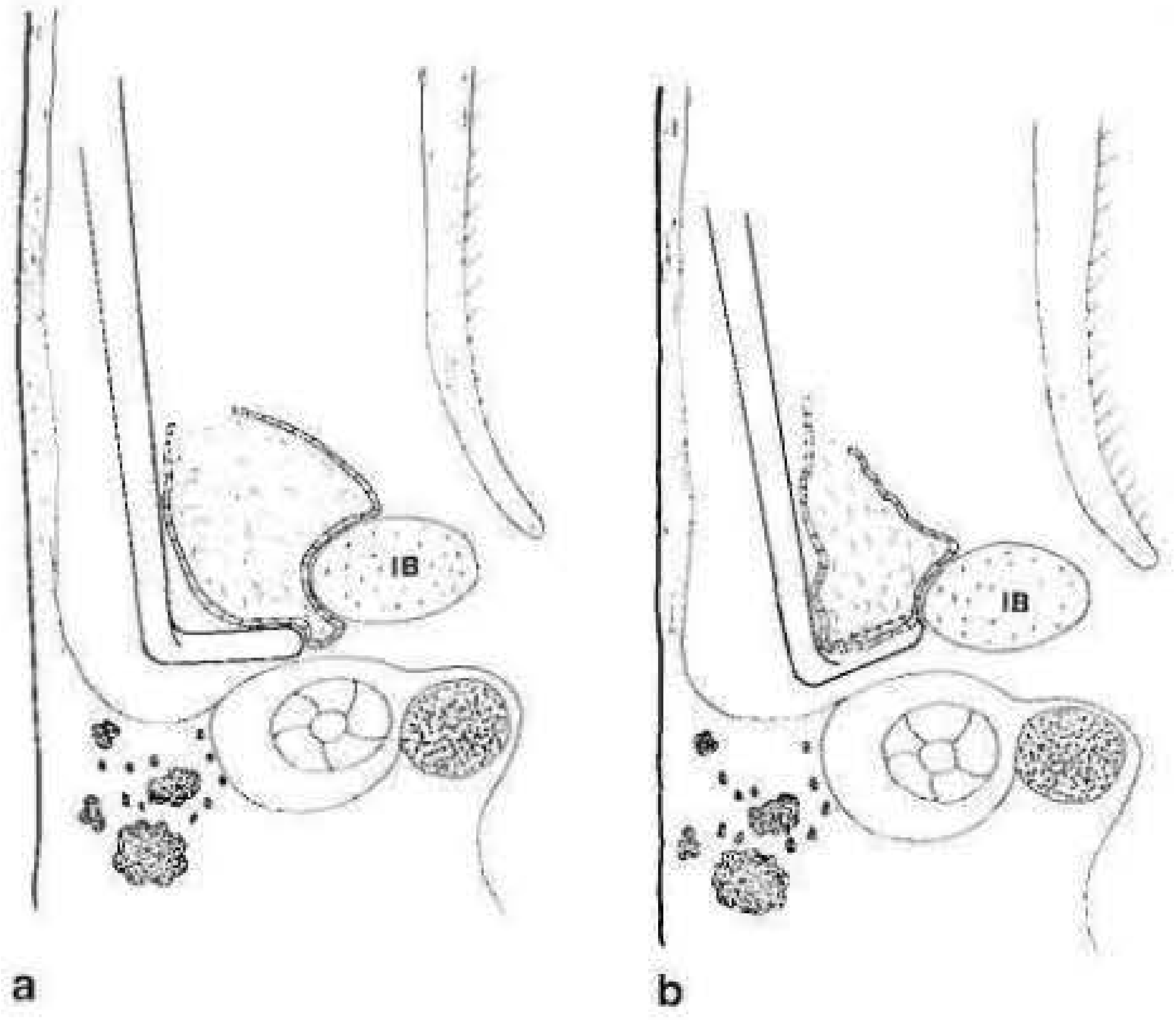


Fig. 334 **Side view of the intact ear canal wall** at the level of the incus body. Elevation of the cholesteatoma membrane from the lateral semicircular canal (**a**) and the medial surface of the incus (**b**)

process of the incus, a large posterior atticotomy has to be performed and the posterior buttress removed in order to elevate this part of the cholesteatoma and still keep the incudostapedial joint intact (Fig. **336**).

Removal of the attic cholesteatoma from the anterior attic and elevation of the membrane from the head of the malleus (Fig. **337 a**) requires extensive drilling of the mastoid tegmen and tegmen tympani to gain the widest possible access to the attic in order to elevate the cholesteatoma membrane. If the cholesteatoma can be removed from the incus body, then it can usually also be elevated from the head of the malleus. The bone from the tegmen tympani is removed, and the cholesteatoma membrane is elevated from the malleus head as far as the anterior bony plate (Fig. **338**). After further careful removal of the cholesteatoma membrane and smoothing of the attic walls, the membrane is

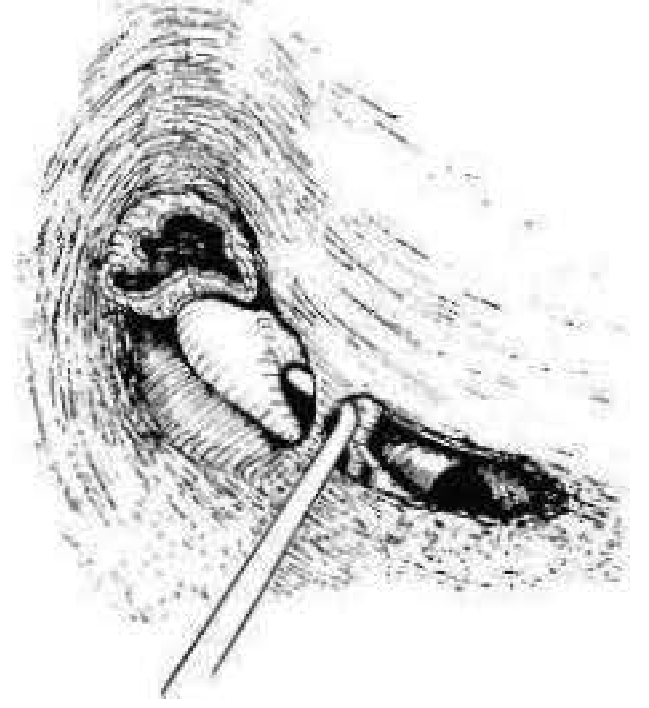


Fig. **335** The incus region has been cleaned, and the posterior atticotympanotomy is performed and the posterior buttress cleaned. Further cholesteatoma remains in the anterior attic, attached to the malleus head

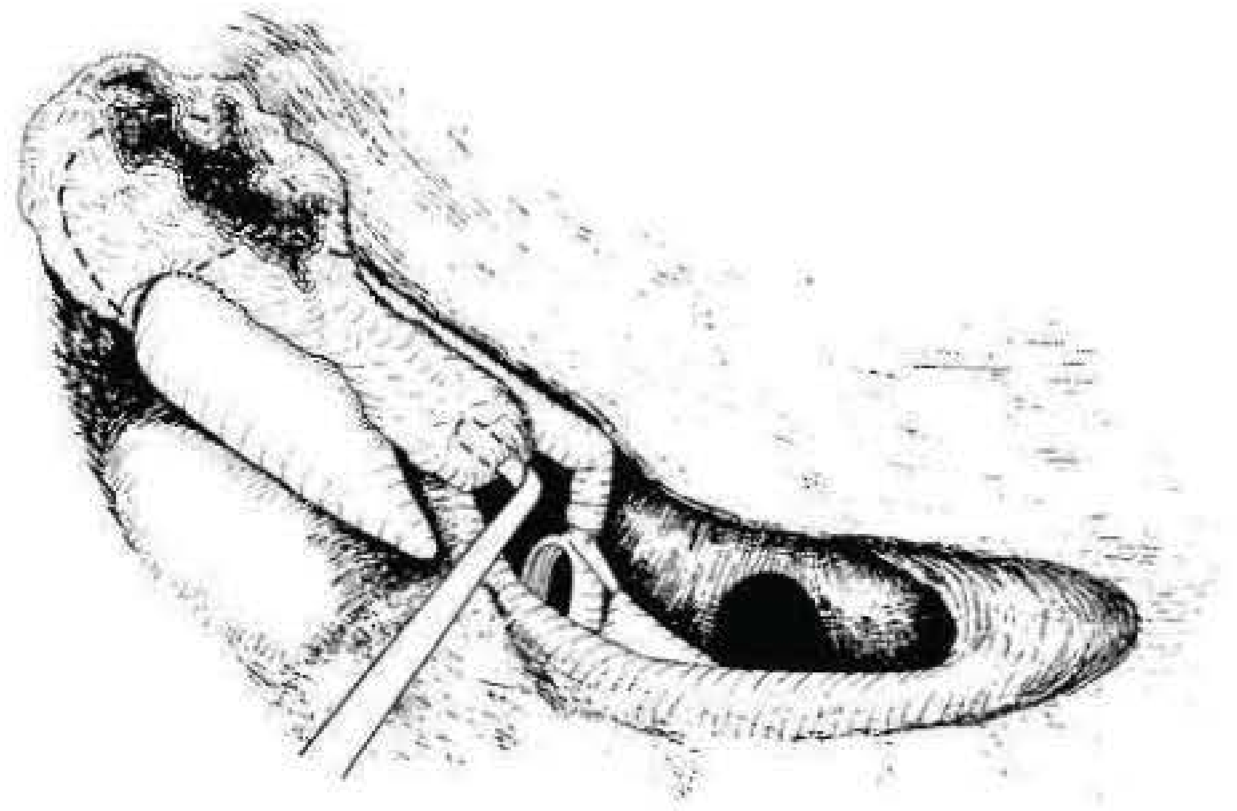


Fig. **336** A protrusion of cholesteatoma extends along the long process of the incus into the tympanic cavity. A posterior atticotympanotomy is performed, the cholesteatoma is elevated, and the ossicular chain is left intact

Fig. 337 **Side view of an attic cholesteatoma in the anterior attic at the level of the malleus head**
a The membrane is elevated from the lateral attic wall in the Shrapnell's membrane region.
b The cholesteatoma membrane is elevated from the edge of the intact ear canal wall and from the superior aspect of the malleus head

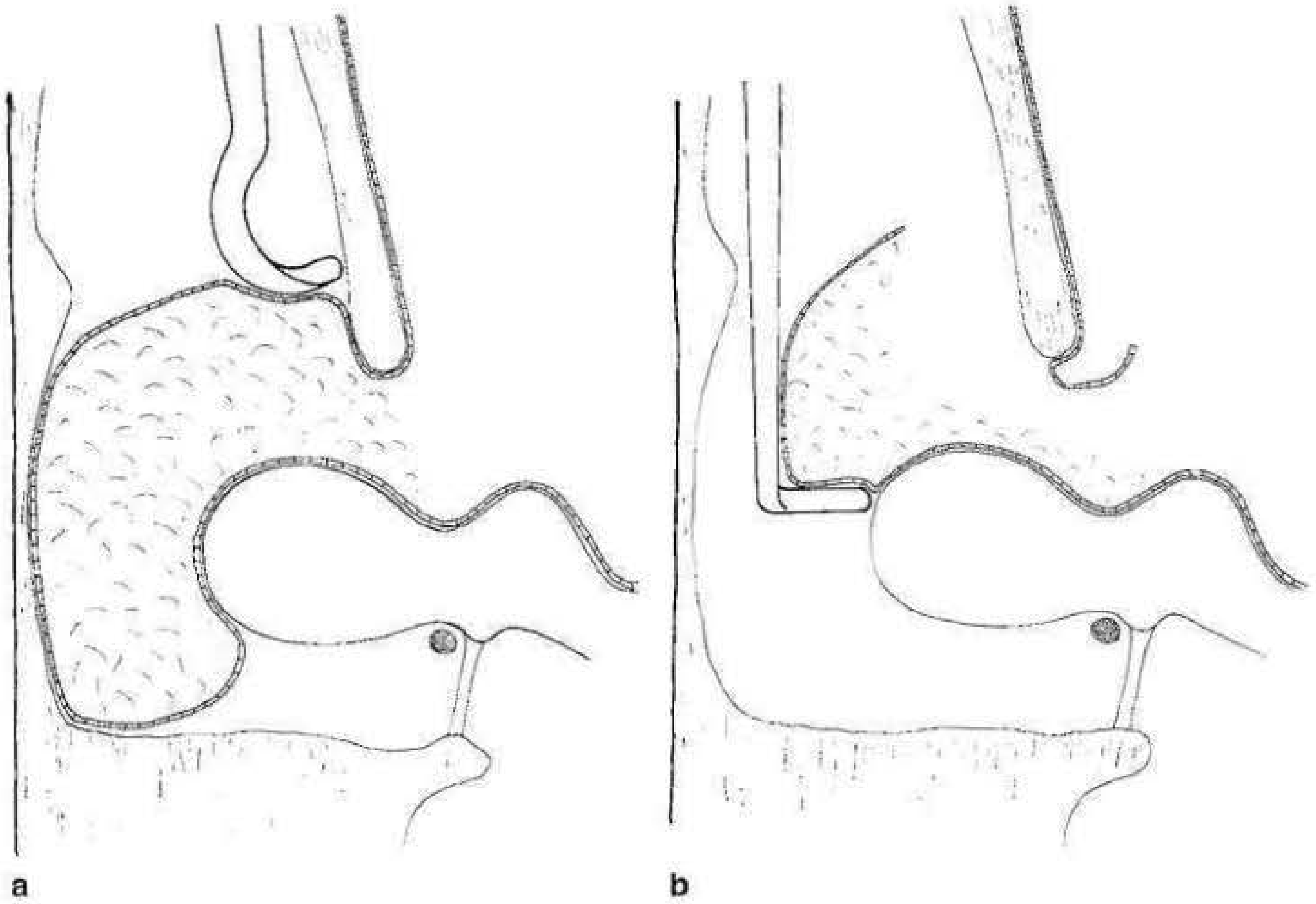


Fig. **338** Elevation of cholesteatoma membrane from the anterior attic. The anterior attic bony plate is indicated (arrow)

Fig. **339** The remaining cholesteatoma, attached to the lateral surface of the malleus head and the neck of the malleus, is removed by pushing it into the ear canal. The anterior bony plate (arrow) will be drilled away in order to expand the access to the epitympanic sinus and the Eustachian tube

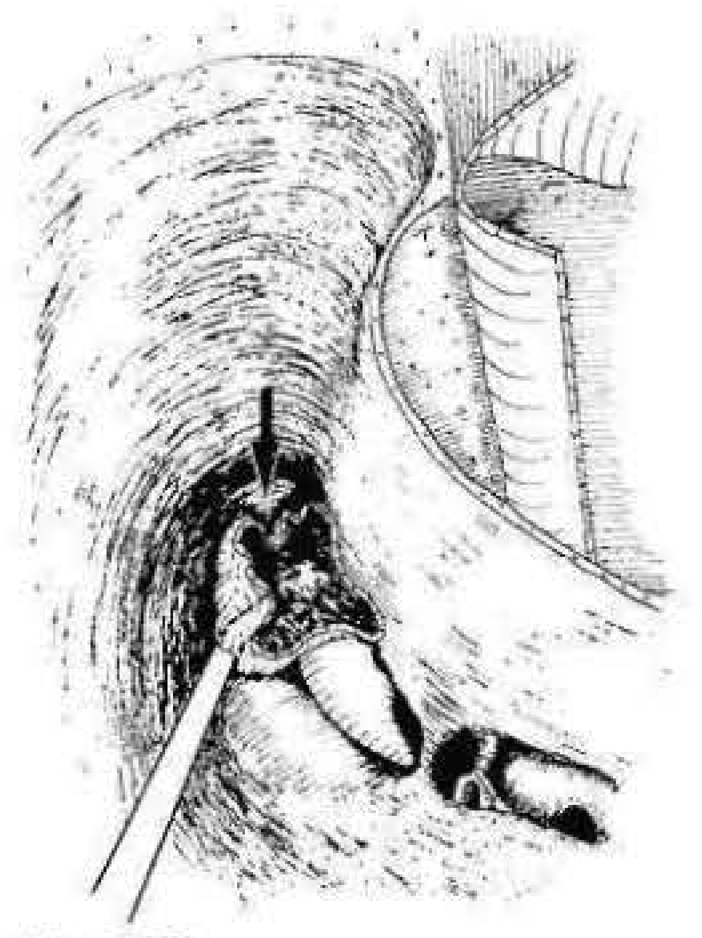


Fig. **338**

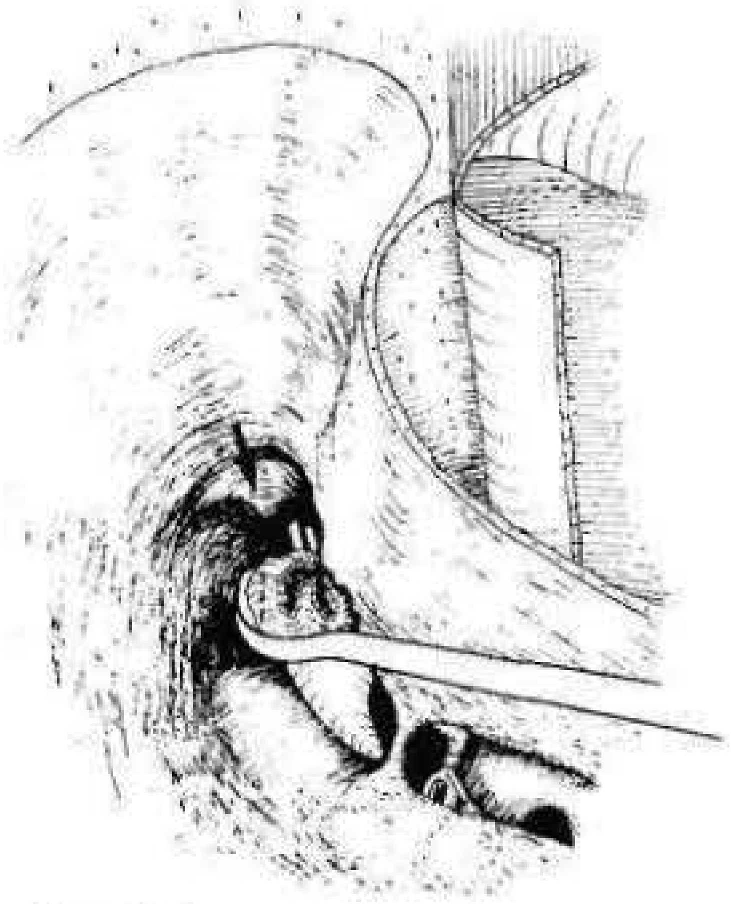


Fig. **339**

removed from the superior and anterior aspect of the malleus head (Fig. **337b**), and the last part of the cholesteatoma membrane can be delivered into the ear canal (Fig. **339**).

After removal of the cholesteatoma, the anterior bony plate is removed (Fig. **339**), opening up the epitympanic sinus and establishing a communication with the Eustachian tube, as shown above (Figs. **309–315**).

Removal of Attic Cholesteatoma in a Disrupted Ossicular Chain

In attic cholesteatoma, the ossicular chain is intact in 26% of ears (Volume 1, p. 243); in 39%, the long process of the incus is resorbed; in 35% the incus body is resorbed, but in only 16% is the stapedial arch resorbed. This means that the ossicular chain will be defective in three out of four cases of attic cholesteatoma (Tos 1979 a). If it is evident that the long process of the incus is not in contact with the stapes, then a large lateral atticotomy and a large posterior atticotympanotomy can be performed (Fig. **340**). The extent of the cholesteatoma can then be established both in the attic and in the posterior tympanum. Removal of the cholesteatoma membrane from the lateral semicircular canal and the incus is safely and repidly performed. After removal of the incus, cleaning the malleus head is easy, because the malleus is mobile. Using an elevator, the cholesteatoma membrane attached to the medial surface of the malleus head is elevated (Fig. **341**), and the anterior attic is cleared of cholesteatoma. The end result is hopefully a completely cleaned malleus head that can be left in place (Fig. **342**).

With further drilling, the transmastoid anterior atticotympanotomy is performed, with removal of the anterior bony plate and establishment of the connection to the epitympanic sinus and the Eustachian tube.

In cases with severe erosion of the malleus head, the head has to be amputated using a punch placed superior to the tensor tympani tendon, the chorda tympani, and the anterior malleolar ligament. The anterior attic can then easily be cleared of cholesteatoma and widened, as previously described. The result is an empty attic with a strong tendency to deep retraction (Fig. **343**).

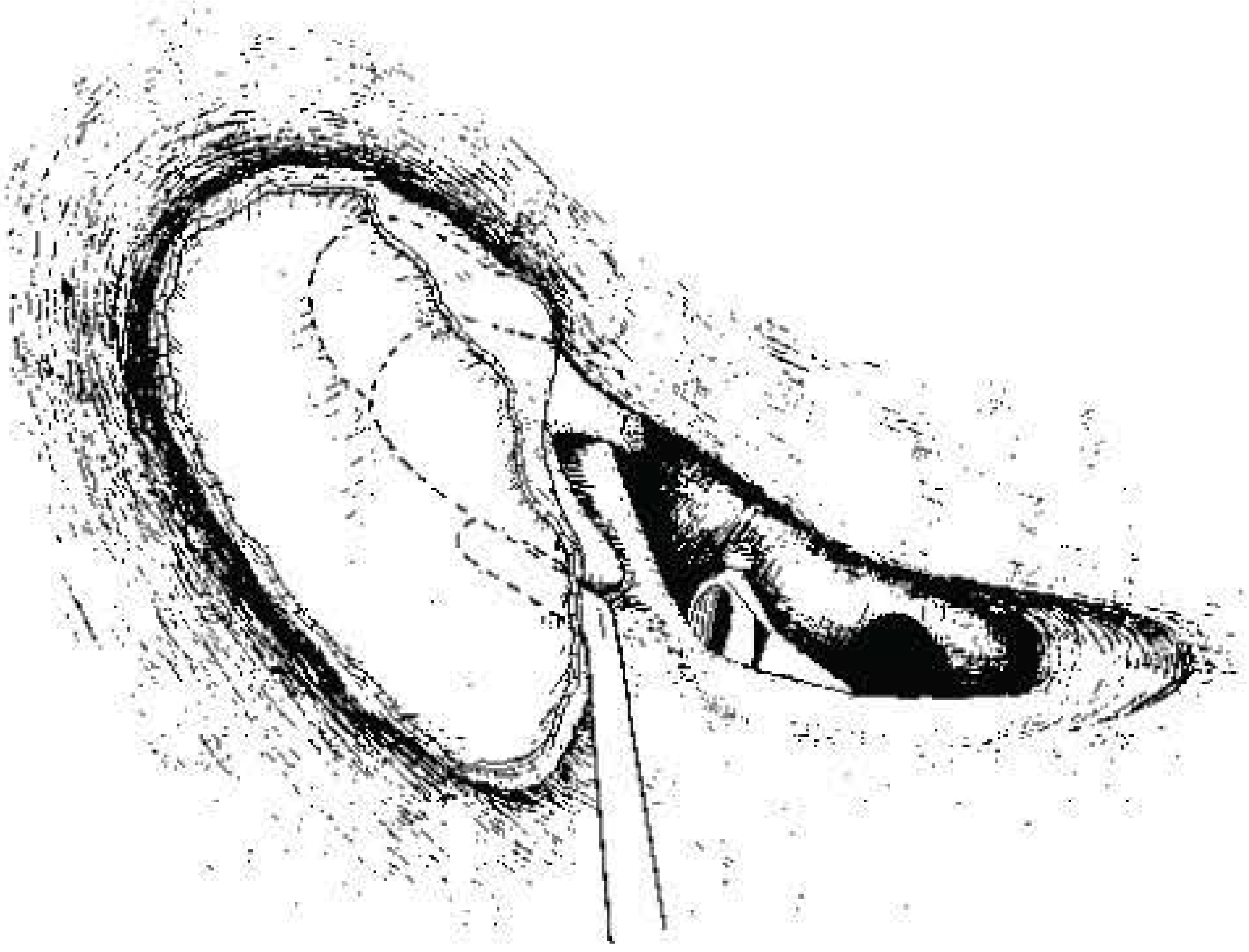


Fig. **340** **Removal of attic cholesteatoma in a defective ossicular chain.** A large posterior atticotomy is performed, and the posterior buttress removed. The long process of the incus is visible, and the membrane from the incus and the prominence of the lateral simicircular canal are elevated

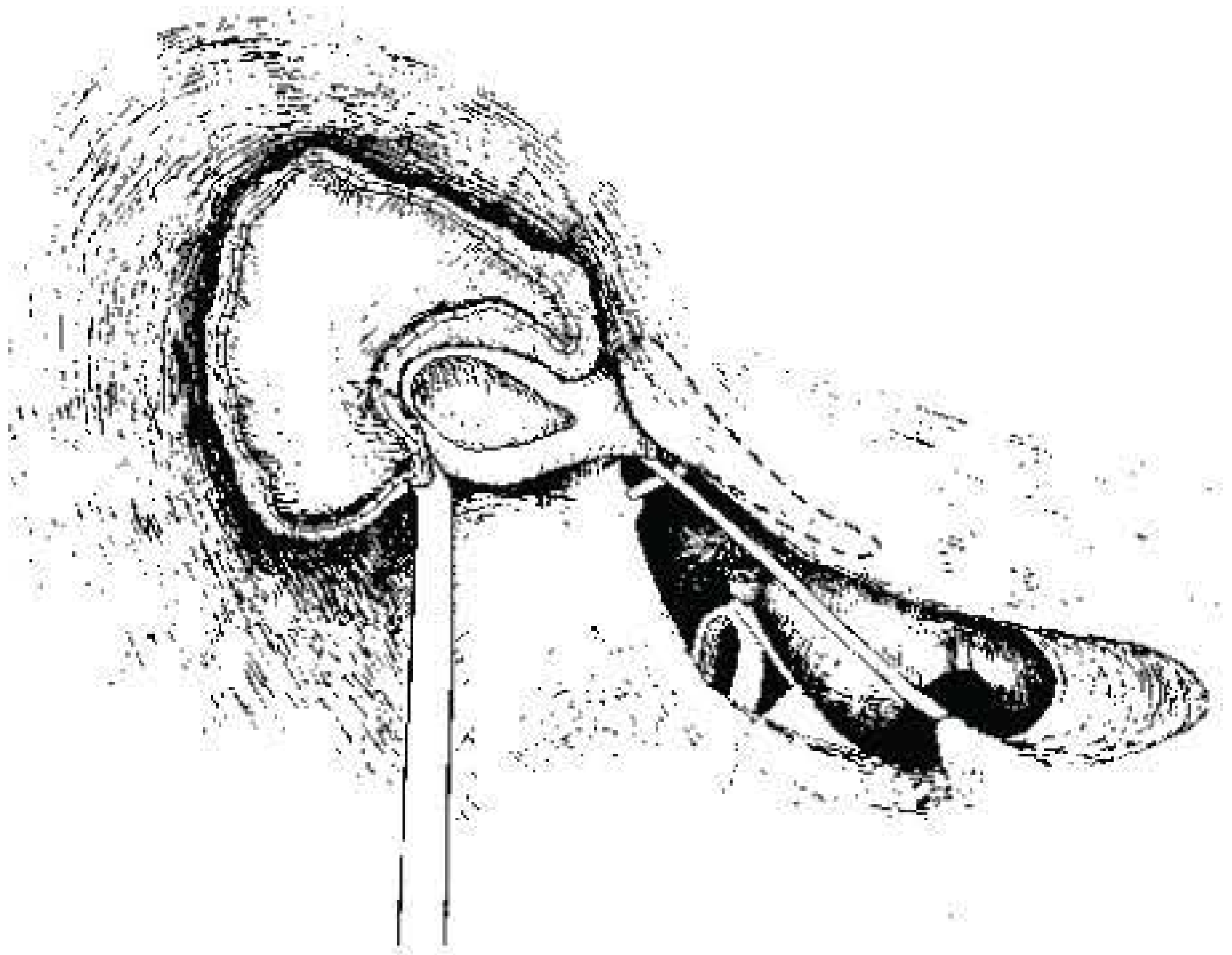


Fig. **341** The defective incus is removed, showing the extension of the cholesteatoma membrane along the malleus head. With a curved rougine, the membrane is elevated from the medial aspect of the malleus head

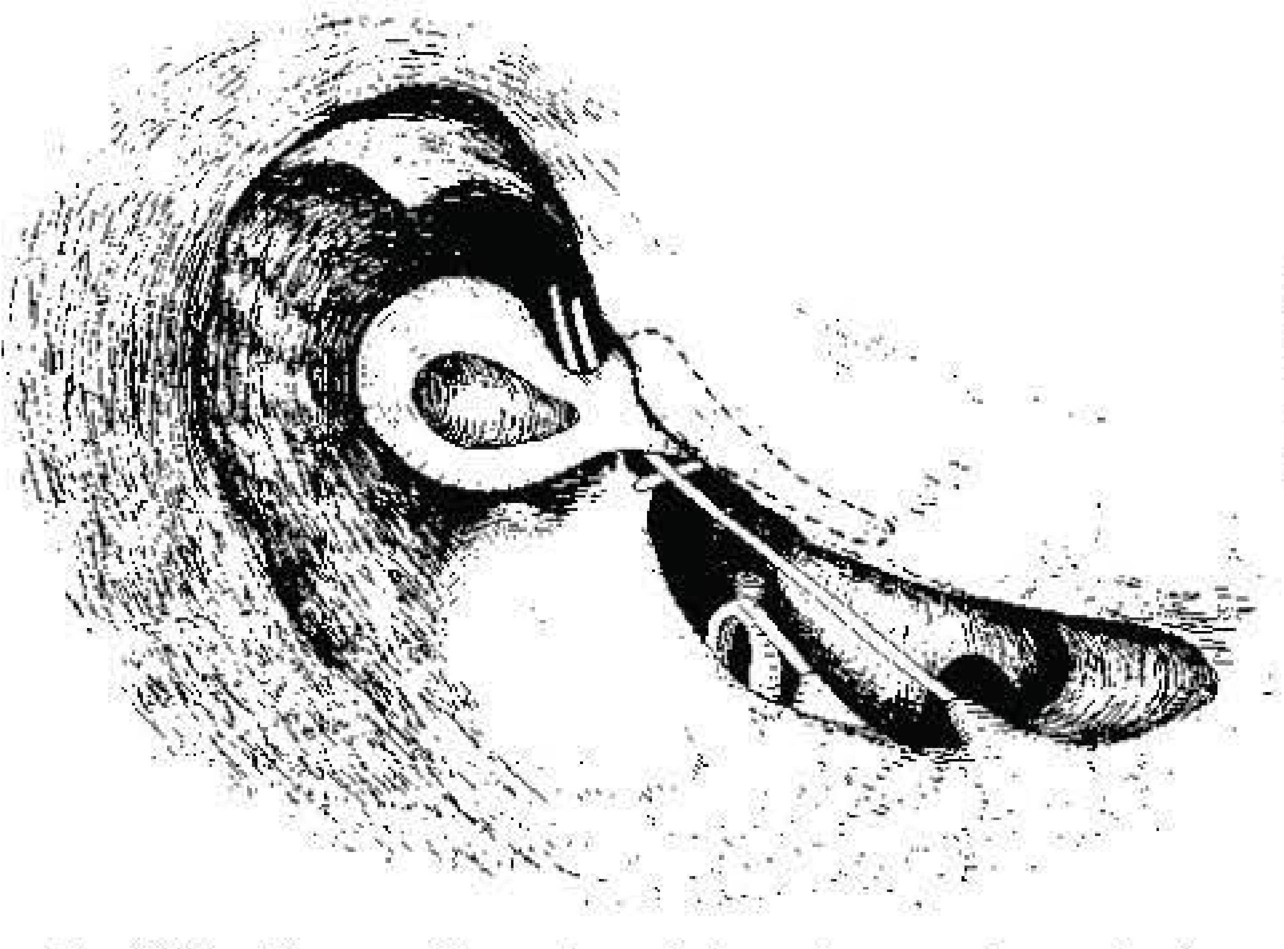


Fig. **342** The malleus head has been cleaned, the cholesteatoma has been removed, and good access to the anterior tympanum and epitympanic sinus is provided

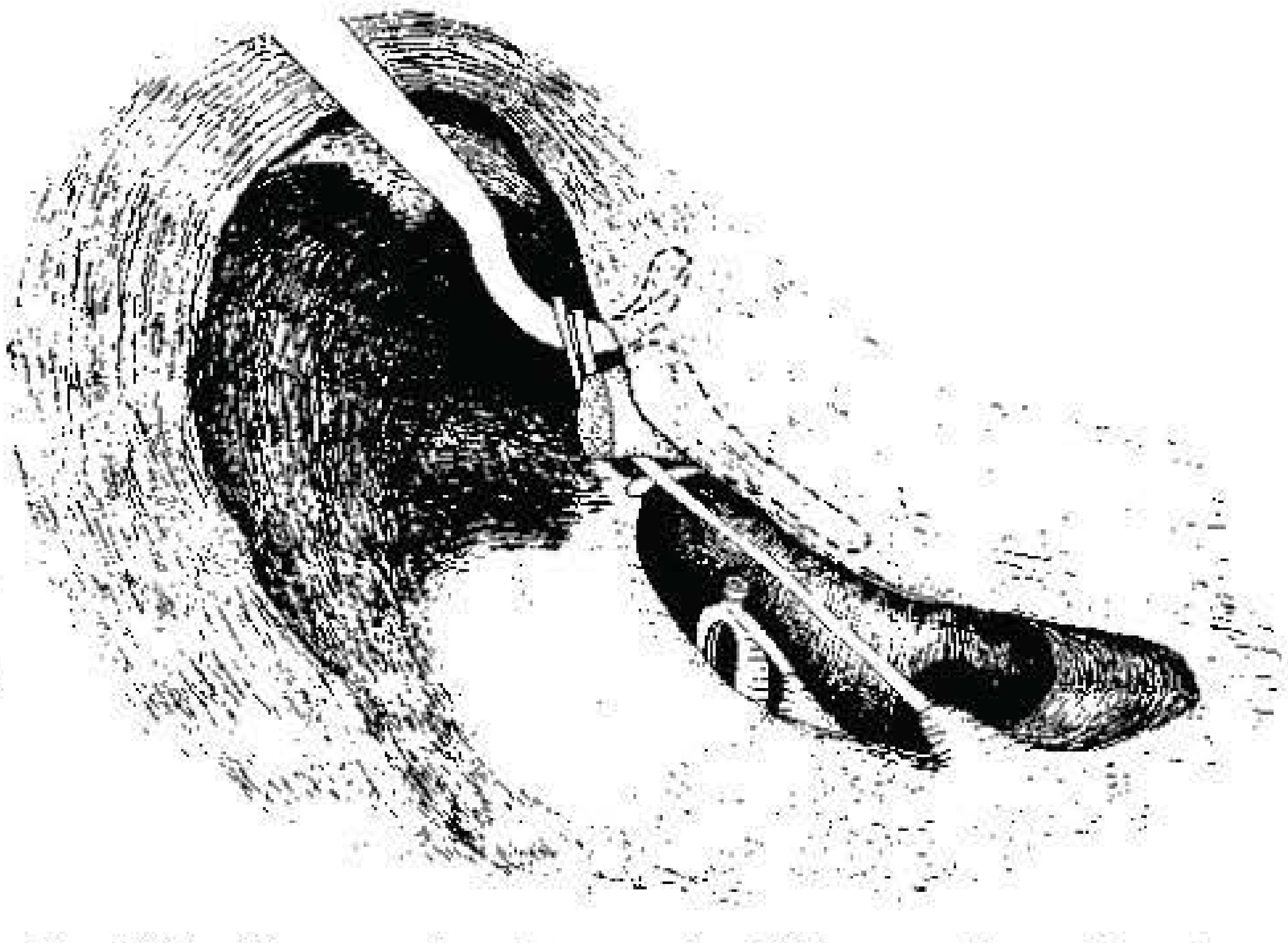


Fig. **343** **Severe involvement of the malleus head, which is resected** and removed together with the cholesteatoma membrane. A rougine is inserted into the epitympanic sinus

Removal of Sinus and Tensa Retraction Cholesteatoma

In sinus cholesteatoma, posterosuperior retraction of the pars tensa continues around the stapes and covers the lateral tympanic sinus, the facial sinus, and the medial sinuses. In sinus cholesteatoma, the ossicular chain is only intact in 10% of cases, the long process of incus is defective in 75%, and the stapedial arch is defective in 40%, strongly suggesting that the major pathology is located in the posterior tympanum where it initially started. The incus body is resorbed in only 13% of cases, and the malleus in only 4%, demonstrating the difference between attic and sinus cholesteatoma (Volume 1, Table **2**, p. 243).

From the posterior tympanum, the sinus cholesteatoma continues along the prominence of the facial nerve, medial to the incus body and toward the attic. In some cases, the sinus cholesteatoma erodes the short process of the incus and the incus body before continuing through the aditus ad antrum. There is usually no cholesteatoma in the lateral and anterior attic. When classic intact canal wall mastoidectomy for cases of sinus cholesteatoma is performed, the cholesteatoma may be visible after the posterior atticotympantomy has been carried out through the facial recess (Fig. **344**). The cholesteatoma membrane covering the facial sinus and the lateral tympanic sinus become accessible after the atticotympanotomy has been extended laterally and inferiorly. Elevation of the cholesteatoma membrane starts inferiorly. The membrane is carefully elevated from the posterior tympanum and the promontory, as well as from the round window niche (Fig. **344**). After cleaning the inferior half of the posterior tympanum, the difficult cleaning of the sinus tympani, posterior tympanic sinus, and stapes footplate region has to be performed (Fig. **345**). The defective incus is extracted, and the remnant of cholesteatoma lying medial to the incus body or partly under the malleus head can now safely be removed (Fig. **346**), resulting in a situation similar to that for attic cholesteatoma with a disrupted chain (Fig. **342**). In sinus cholesteatoma, it is seldom necessary to resect the malleus head. Usually, the cholesteatoma can be safely cleared from under the malleus head and around the tensor tympani tendon.

Tensa retraction cholesteatoma is a result of retraction of the entire pars tensa, draped over all the walls of the tympanic cavity, extending into the tympanic orifice, and from there under the anterior malleolar fold towards the attic. In the posterior tympanum, this situation is similar to sinus cholestea-

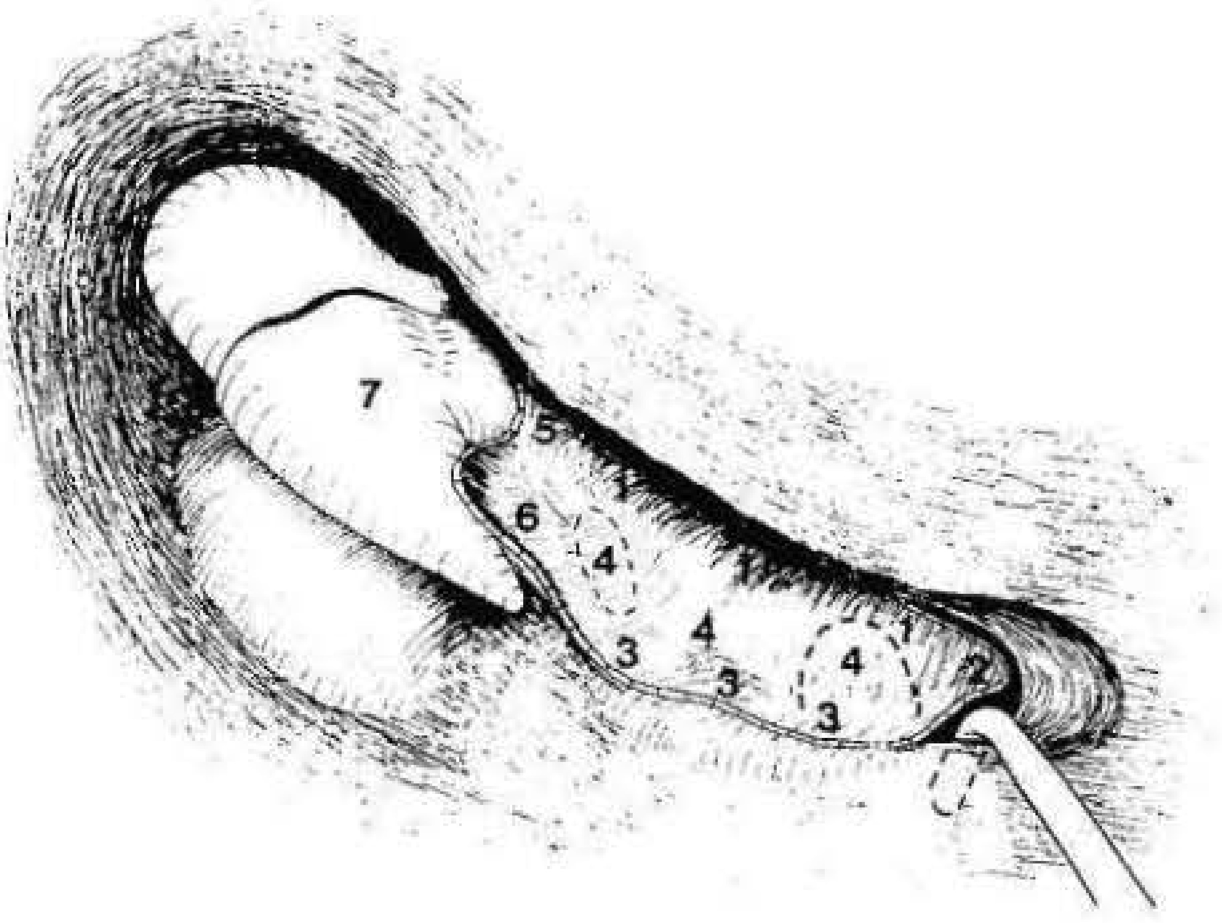


Fig. **344** **Extension of sinus cholesteatoma as seen through the posterior atticotympanotomy.** The anterior wall of the cholesteatoma membrane emerges as a retraction from the atrophic drum along the malleus handle. It is attached (1) to the posterior aspect of the promontory; (2) to the styloid eminence inferiorly, to the lateral tympanic sinus posteriorly, and to the facial sinus and (3) the pyramidal eminence. Medially, it covers (4) the round window niche (dashed), the sinus tympani, and the footplate region. Superiorly, it convers (5) the defective incus, which is partly resorbed, and (6) the eminence of the horizontal part of the facial nerve. It may extend (7) under the incus body to the tympanic isthmus. The inferior part of the membrane is elevated by a curved rougine through the posterior atticotympanotomy

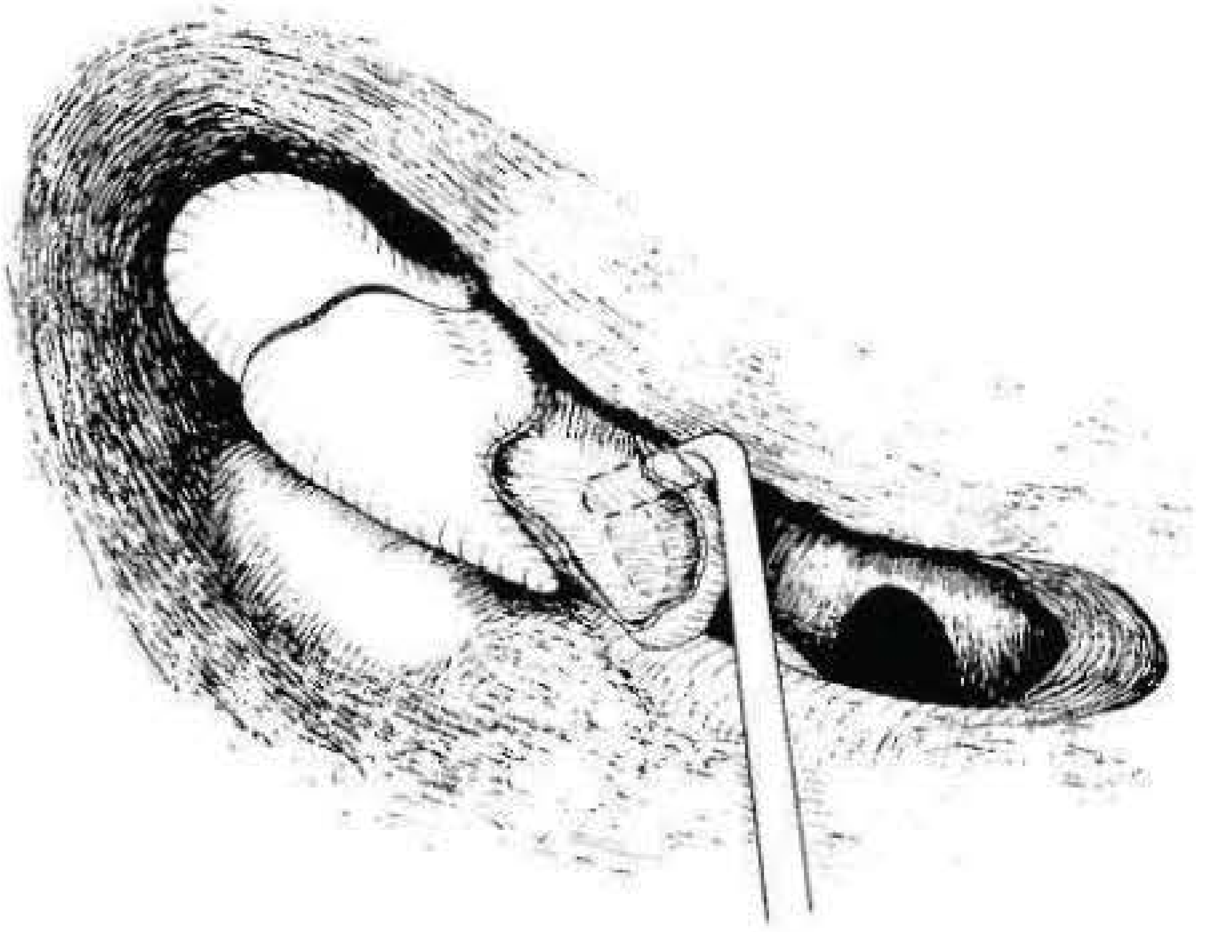


Fig. **345** **Removal of the sinus cholesteatoma through the posterior atticotympanotomy.** The membrane in the inferior and medial aspects of the posterior tympanum is elevated using a curved rougine

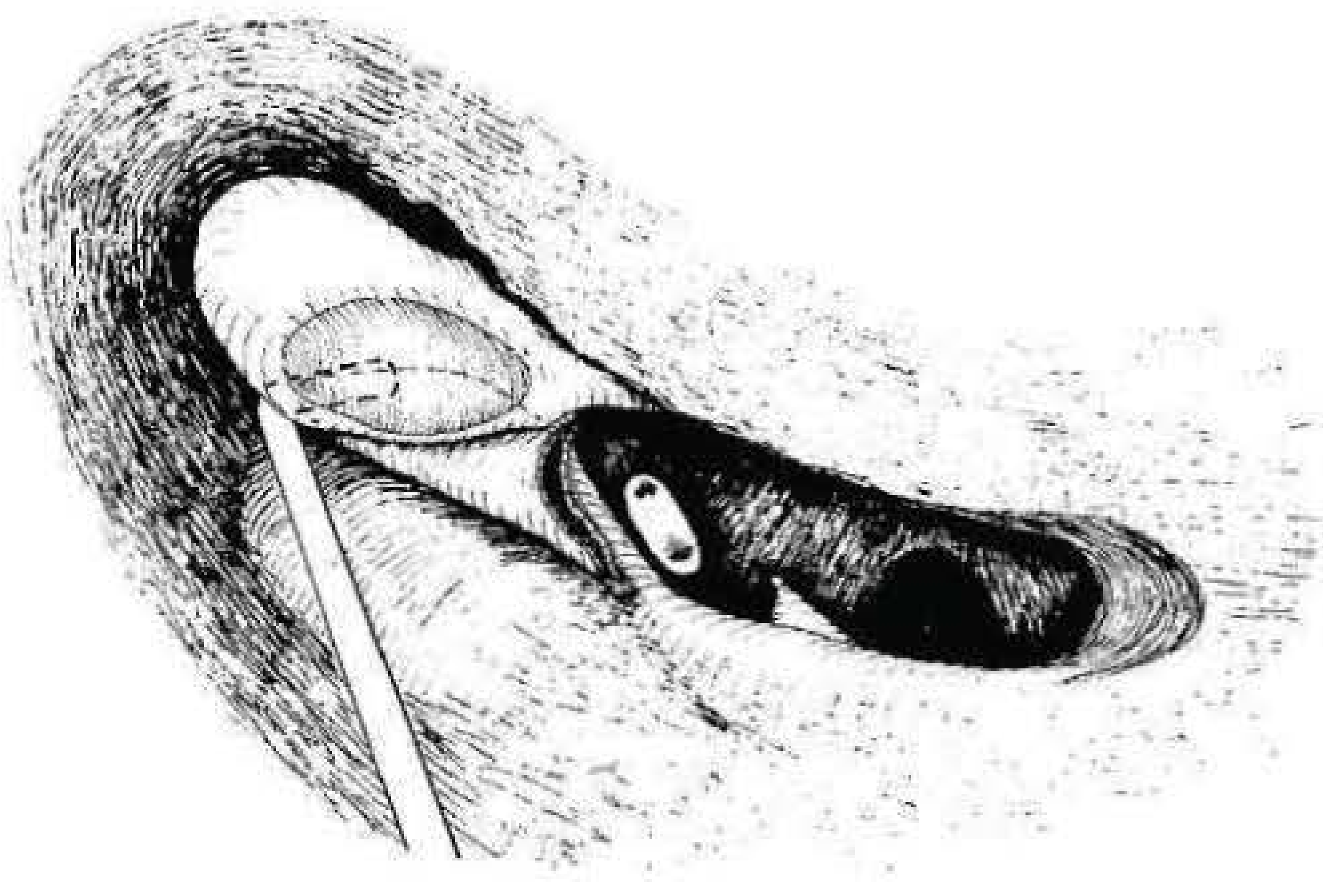


Fig. **346** The incus is removed, and the extension of the cholesteatoma under the incus body and malleus head is elevated

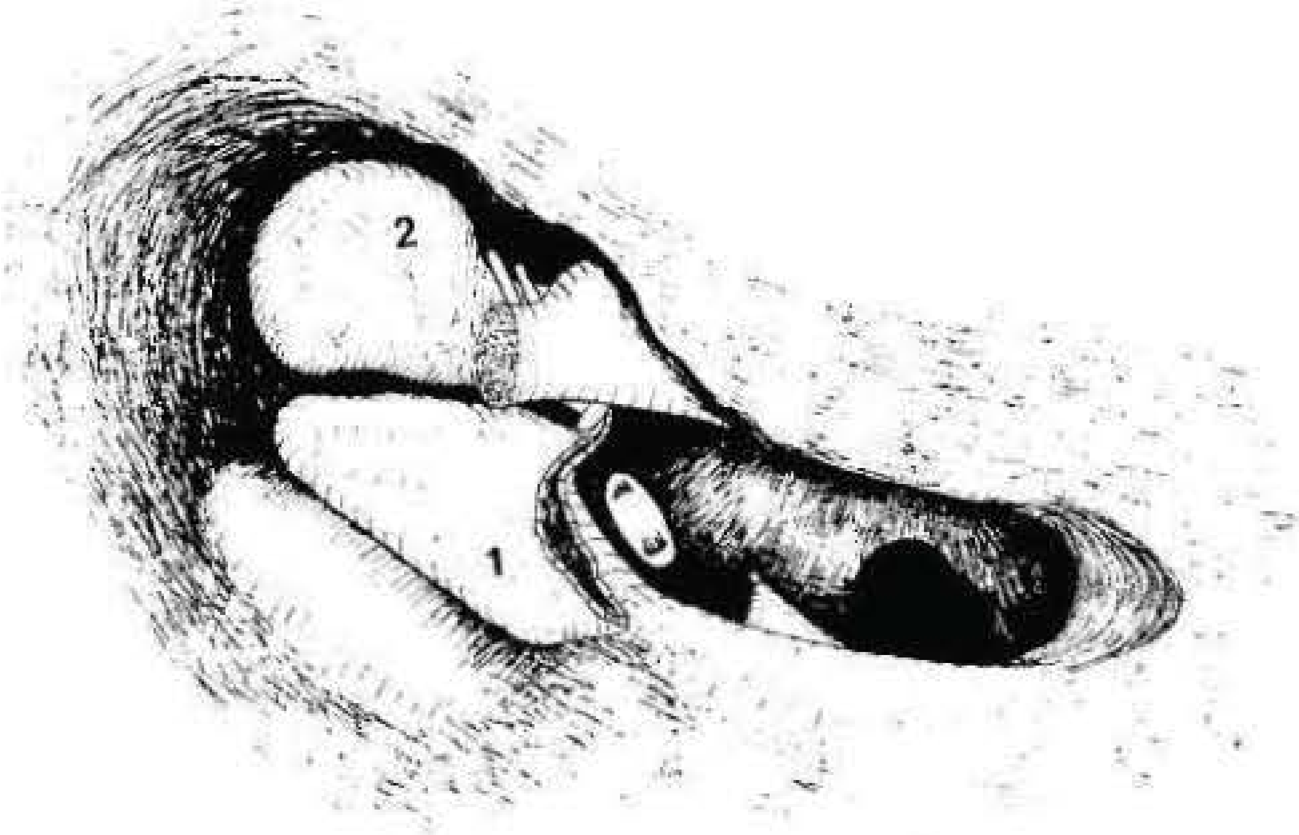
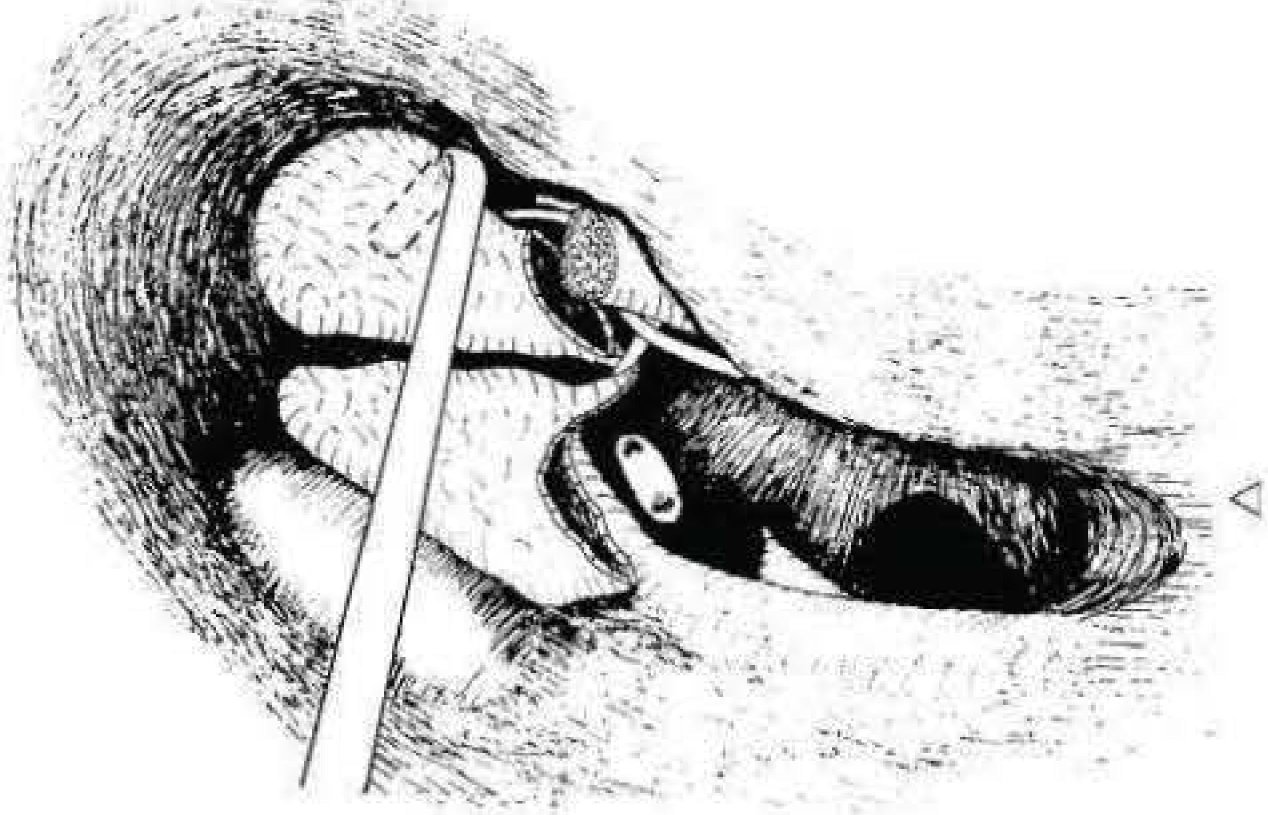


Fig. **347** **Extension of tensa retraction cholesteatoma,** illustrated in a classic intact canal wall mastoidectomy and large posterior atticotympanotomy situation, with a removed incus and resected malleus head. One part of the membrane runs posterior to the tendon of the tensor tympani muscle (1), and the other anteriorly, reaching the anterior attic under the chorda tympani and the anterior malleolar ligament (2)

toma, with the cholesteatoma membrane covering the promontory and the posterior tympanum, where it usually causes resorption of the long process of the incus and the stapes crura. After a large posterior atticotympanotomy similar to that described in sinus cholesteatoma (Fig. **344**), the work necessary in tensa retraction cholesteatoma in the posterior tympanum is the same as that for sinus cholesteatoma, i. e., removal of the cholesteatoma membrane from the posterior tympanum (Fig. **345**), extraction of the incus (Fig. **346**), and removal of the cholesteatoma from the tympanic isthmus, the horizontal part of the facial nerve, and the prominence of the lateral semicircular canal (Fig. **346**).

In contrast to sinus cholesteatoma, tensa retraction cholesteatoma may extend under the anterior malleolar fold toward the attic, and in such cases it is necessary to resect the malleus head in order to visualize and remove all the cholesteatoma in the attic (Fig. **347**). Sometimes the tendon of the tensor tympani muscle has to be resected in order to lateralize the remnant of the malleus (Fig. **348**). In tensa retraction cholesteatoma, the malleus handle is often resorbed, and in this type of cholesteatoma, the major part of the work has to be done in the tympanic cavity, because the cholesteatoma covers all the walls of the tympanic cavity. This part of the surgery has to be performed through the transmeatal route, resulting in total perforation and an absent malleus handle.



◁ Fig. **348** **Removal of tensor retraction cholesteatoma from the attic.** The tendon of the tensor tympani muscle is cut and the malleus remnant elevated, visualizing the anterior extension of the tensa retraction cholesteatoma into the attic. The cholesteatoma is elevated

Scutumplasty

Repair of bony ear canal wall defects in classic intact canal wall mastoidectomy or atticoplasty is termed *scutumplasty* by Sakai et al. (1986). The defect is usually at the Shrapnell's membrane region, and is caused by the attic cholesteatoma, but a defect may also be caused surgically during thinning of the ear canal wall, either accidentally or deliberately, in order to gain better access to the anterior attic. Some variations of classic intact canal wall mastoidectomy techniques include partial removal of the lateral attic wall (Morimitsu 1991, Rosborg 1993, Honda 1992).

Defects in the lateral attic wall may therefore be caused by 1) disease—attic cholesteatoma; 2) atticotomy; 3) classic intact canal wall mastoidectomy; 4) previous atticotomy or intact canal wall mastoidectomy; and 5) combinations of 1 to 4.

After the initial enthusiasm for the intact canal wall technique, it soon became evident that attic retraction tends to recur, often resulting in the same disease as before—retraction cholesteatoma in the attic or posterior tympanum. Prevention of such retraction became imperative in the late 1960s, and several methods of scutumplasty were described and used: with autogenous cartilage (tragal and conchal), allogenous cartilage (septum, knee, or costa), autogenous orthotopic bone, allogenous bone, bone paté, and some biocompatible materials.

Scutumplasty with Autogenous Cartilage

Cartilage and perichondrium have been used in ossiculoplasty and myringoplasty since the early 1960s (Volume 1, pp. 277, 286).

Tragal cartilage. McCleve was the first to use tragal cartilage in scutum repair after classic intact canal wall mastoidectomy (McCleve 1969, 1985). The tragal cartilage is used as a compound graft together with the perichondrium, as a free graft, or as thin slices. The attached perichondrium helps to anchor the cartilage both to the canal wall and to the adjacent tympanic membrane. It is easy to adapt and fix to the bone during surgery, and it remains stable after surgery. Even though a free cartilage graft can be used, the compound graft is easier to use and more reliable in maintaining its original position in the bony defect. It is also less prone to retraction. In addition, it has been shown that the attached perichondrium may improve the viability of cartilage in the middle ear (Steinbach and Pusalkar 1981). McCleve (1969, 1985), using composite tragal perichondrium–cartilage grafts, reported good results in scutumplasty.

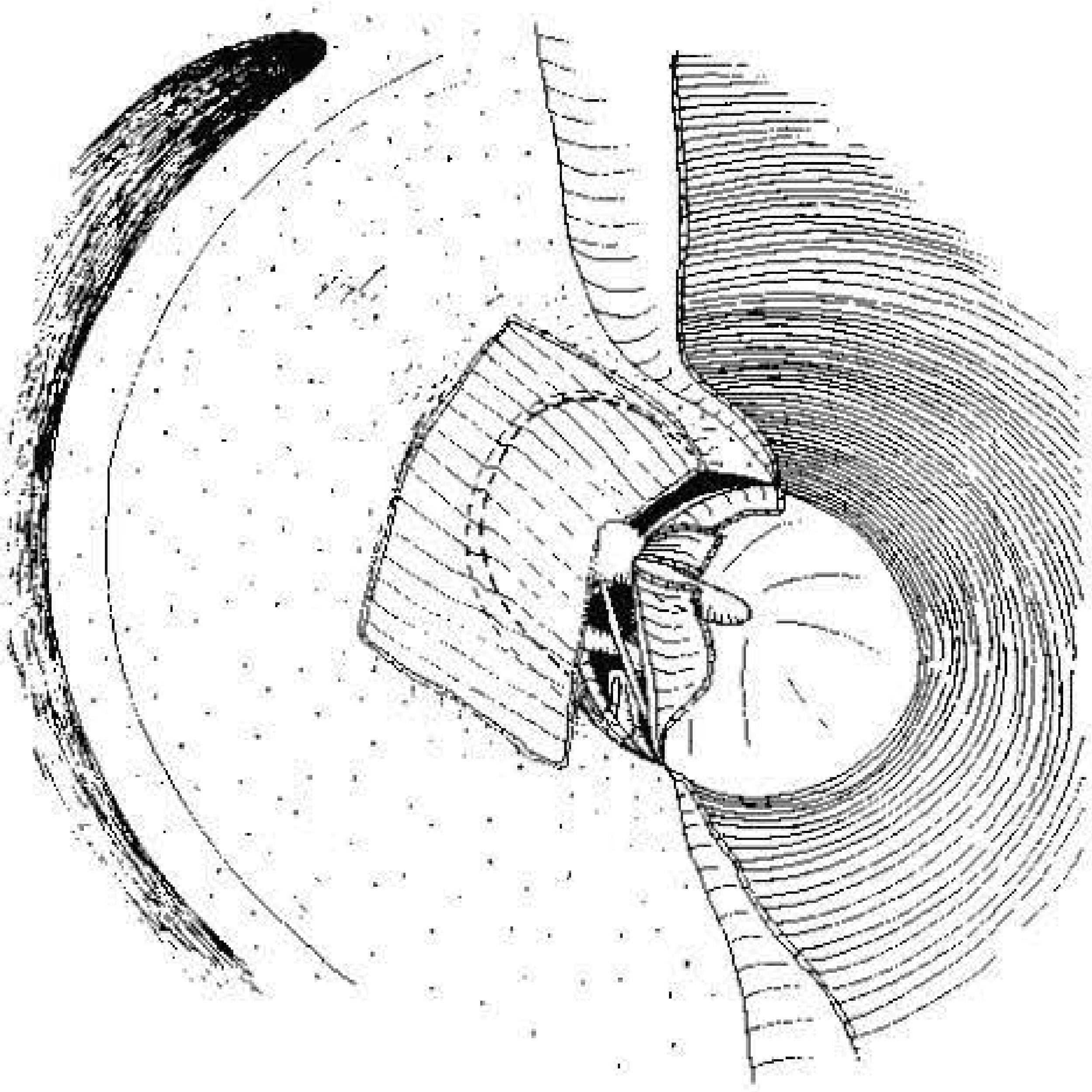


Fig. **349** **Scutumplasty (McCleve), with a compound tragal cartilage–perichondrium graft** placed on the meatal side of the ear canal wall. The cartilage has been fitted into the defect in the attic, and touches the malleus neck. The perichondrium covers the surroundings of the defect

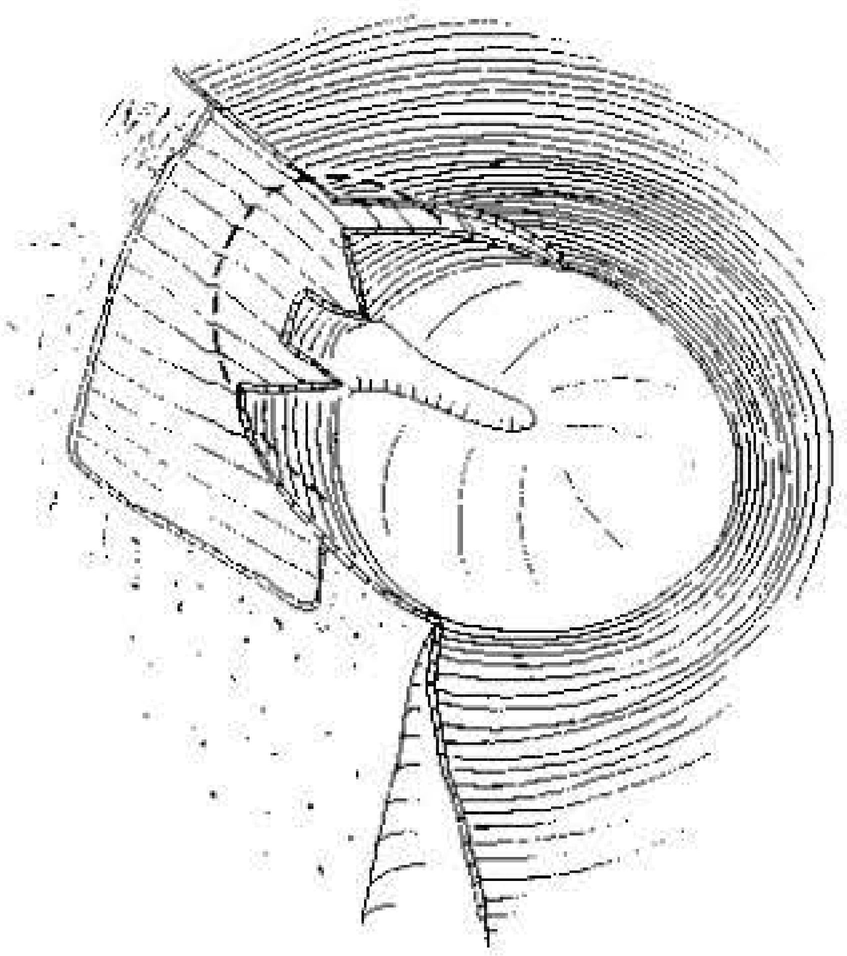


Fig. **350** The ear canal skin flaps are replaced, including the malleus flap

The tragal cartilage with perichondrium is harvested as shown in Volume 1 (pp. 97–101), adapted to the size of the defect, and placed in the defect (Fig. **349**), with the cartilage spread over the meatal surface of the ear canal. After replacing the ear canal skin flaps (Fig. **350**), the closure of the defect is quite firm. The cartilage–perichondrium graft has been used in several ways (McCleve 1985), e. g., with the perichondrium placed onto the meatal surface of the ear canal, and also onto the short process of the malleus (Fig. **351a**) (Fleury 1974, Adkins and Osguthorpe 1984, McCleve 1985, Hildmann 1991); or onto the mastoid surface of the bony ear canal and onto the malleus head (Fig. **351b**). In small defects of the scutum, part of the perichondrium lies on the meatal side of the ear canal, before being turned onto the meatal side and then onto the malleus remnant (Fig. **352a**) (McCleve 1985).

In larger scutum defects, the perichondrium, attached to both sides of the tragal cartilage, can be placed on both sides of the ear canal wall (Fig. **352b**). Fleury (1971) detaches the drum from the malleus handle and places the cartilage–perichondrium composite graft in contact with the short process of the malleus (Fig. **353**). Kinney (1982), using a similar technique, has reported good results in scutumplasty using compound tragal cartilage–perichondrium grafts.

The lateral half of the tragal cartilage, with the perichondrium attached on both sides, must be used in order to achieve a large compound graft (Fig. **354 a**).

The appropriate size of cartilage in relation to the bony defect can be achieved by cutting a piece of Silastic to the exact size of the bony defect as a template (Zini 1994). The Silastic is trimmed to the correct size and placed on the cartilage–perichondrium graft. The superfluous cartilage is then removed (Fig. **354b**).

Tragal cartilage as a *free graft* is usually placed on the meatal side of the ear canal wall, rarely in the defect itself, due to the risk of displacement or retraction into the attic. Honda (1992) first places a fascia graft, carefully glued to the drum in order to cover the attic defect, and then the free cartilage (tragal or conchal) graft, trimmed exactly to fit into the defect. The fascia and the graft are glued to the bone with fibrin glue (Figs. **355, 356**).

Sheehy (1990) uses sliced tragal cartilage (Fig. **357**) placed on the meatal surface of the defective attic wall, but this is usually performed in second-stage surgery. In the first stage, a piece of thick Silastic is placed in the attic to prevent retraction through the bony defect. The Silastic is replaced by sliced tragal cartilage during the second stage.

Sometimes a large piece of cartilage is placed on the head of the stapes, continuing up to the attic (Sheehy 1990) in contact with the medial edge of the bony defect (Fig. **358**). If the malleus head is present and only the incus is missing, this type of construction is stable, allowing the cartilage to maintain contact with the malleus head and prevent retraction into the posterior attic.

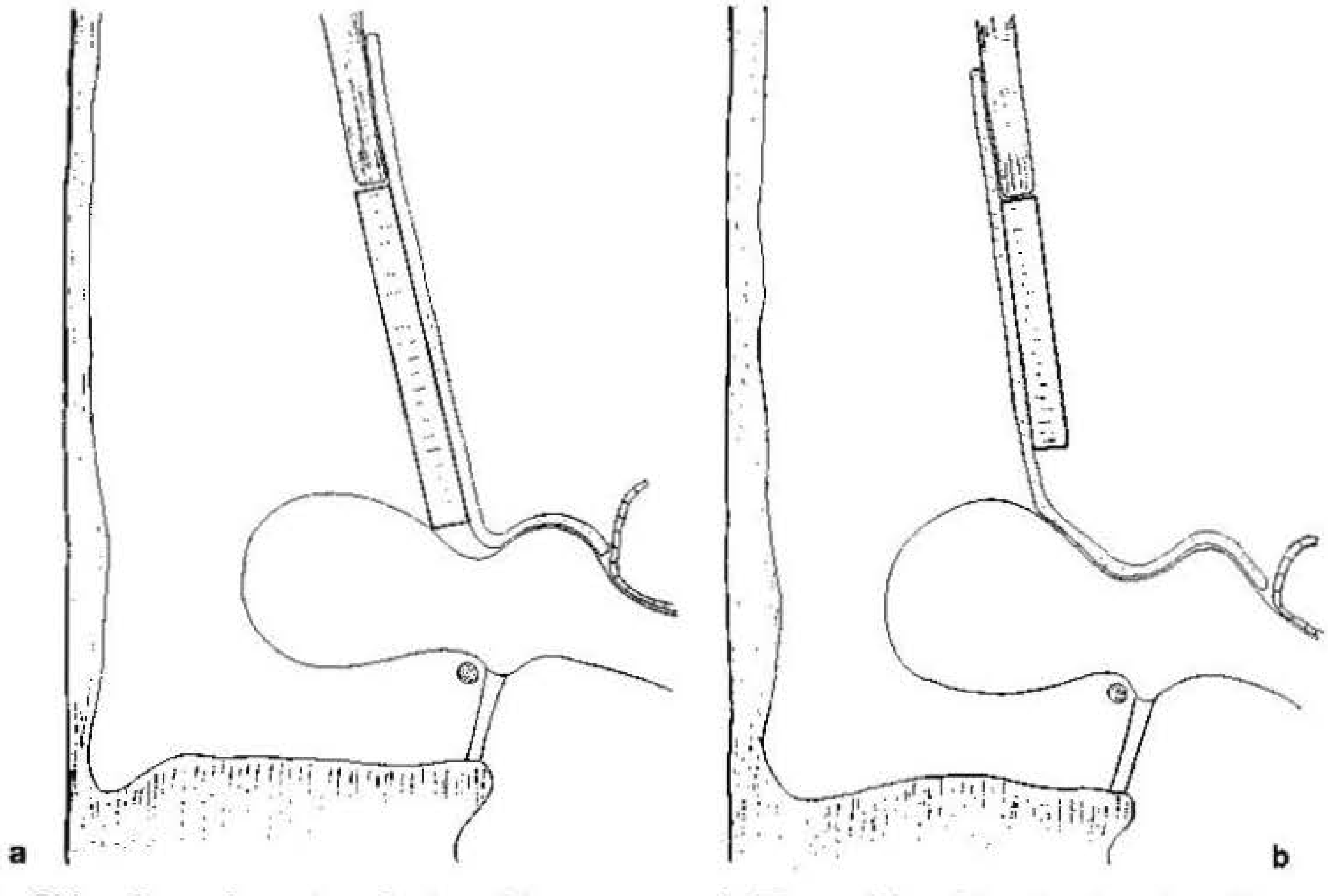


Fig. 351 **Side view of scutumplasty with a compound tragal cartilage–perichondrium graft.**

a The cartilage is touching the neck of the malleus, and the perichondrium is placed on the meatal surface of the bony ear canal wall and on the short process of the malleus

b The perichondrium is placed on the mastoid surface of the bony ear canal and on the malleus head and short process of the malleus

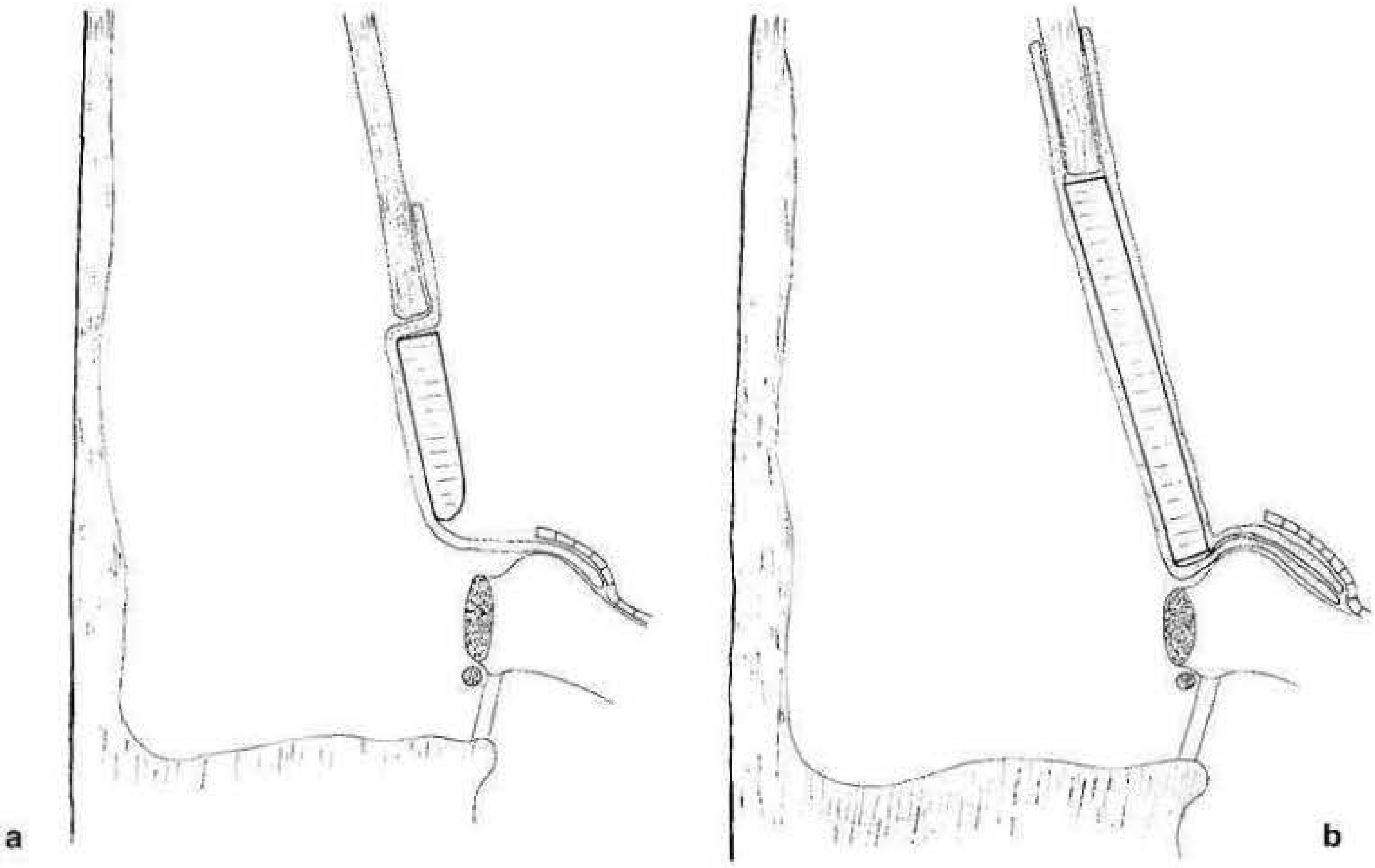


Fig. **352** **Side view of scutumplasty with tragal cartilage–perichondrium compound graft in cases with resected malleus head.**

a In a small scutum defect, the perichondrium is placed on the meatal surface of the ear canal, and then turned inside the cartilage and placed on the malleus remnant

b The double covering of the ear canal with perichondrium. The perichondrium attached to the cartilage is placed both on the meatal and on the mastoid surfaces of the ear canal. Both ends of the perichondrium are placed on the short process of the malleus and the malleus handle. The attic is empty, and the head of the malleus is extruded

Conchal cartilage is used in a similar way to tragal cartilage, both as a free graft (Portmann 1979, Chiossome 1985, Honda 1992) or a compound graft. Conchal cartilage is somewhat thinner than tragal cartilage, but it has a curvature similar to that of the ear canal (Fig. **359**). Linde (1973) has achieved good results using compound conchal cartilage–perichondrium grafts covering attic defects and the bony defects of the superoposterior wall, as well as preventing posterior retraction of the drum in tympanoplasty.

Other authors have also reported good results using cartilage with attached perichondrium (Eviatar 1978, Adkins and Osguthorpe 1984).

Autogenous **septal cartilage,** harvested from the anterior part of the septum, is relatively thick. It can be placed in the scutum defect, but its shape is usually not concave, and it seems to be difficult to keep in place.

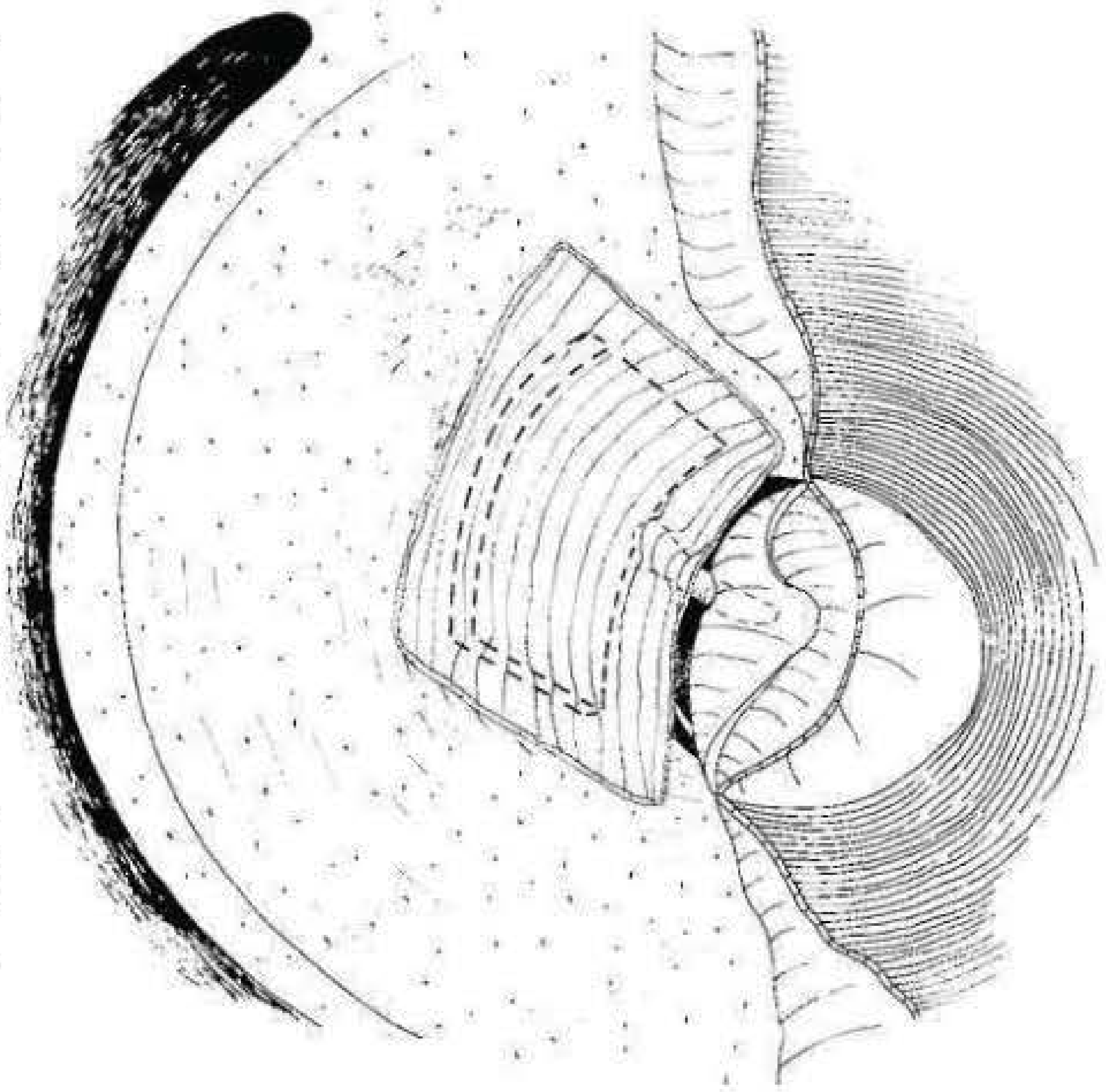


Fig. **353** **The Fleury scutumplasty method,** using a compound tragal cartilage–perichondrium graft. The upper part of the drum is elevated from the malleus handle, and the perichondrium is placed on the malleus handle and on the meatal surface of the bony ear canal. The cartilage is placed on the malleus neck

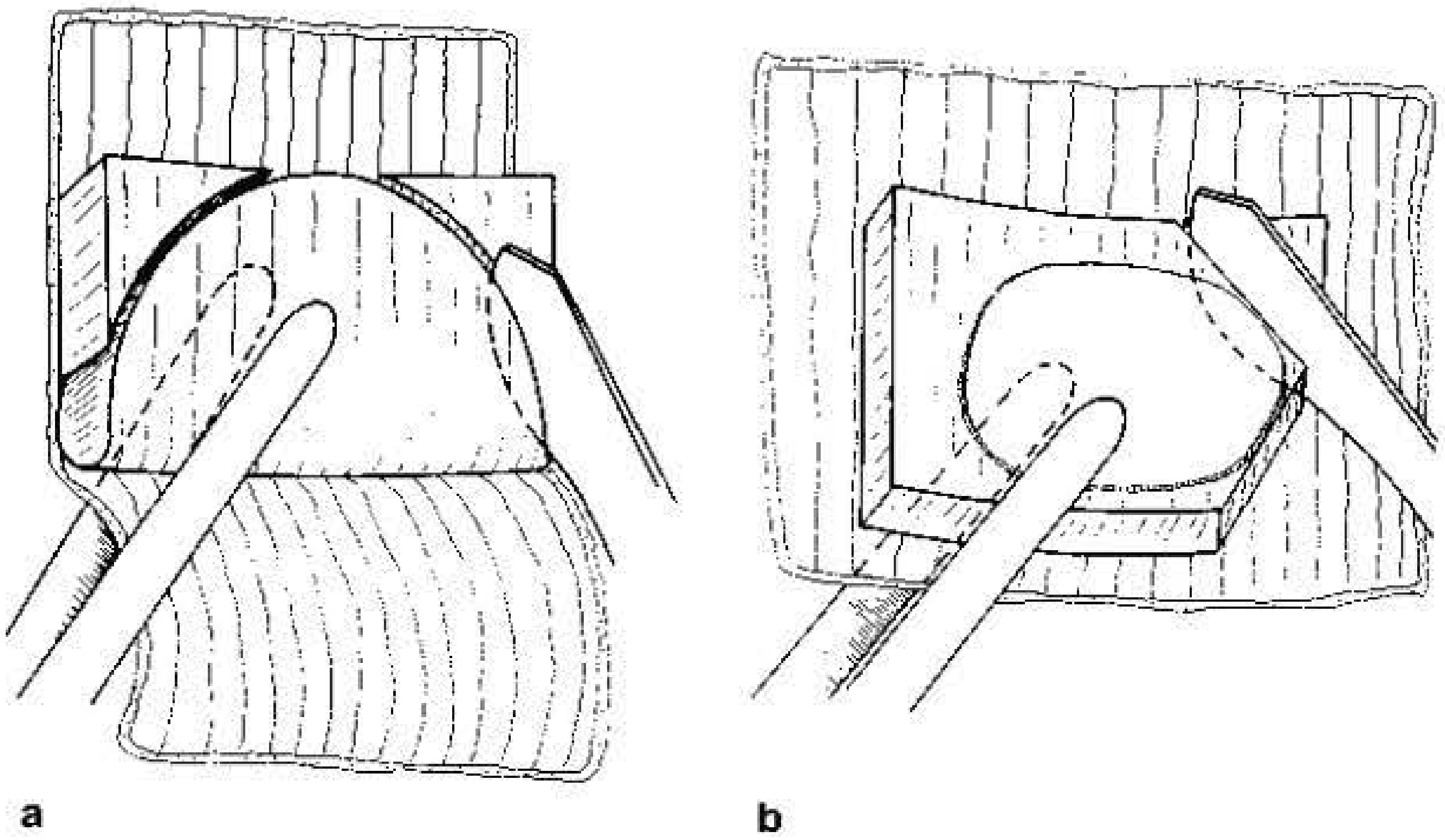


Fig. **354a** Cutting the cartilage–perichondrium compound graft out of the lateral half of the tragal cartilage with perichondrium, to be applied as indicated in Figure **352a.** The perichondrium is elevated from the cartilage on one side, and the cartilage is trimmed to the proper size.
b Cutting the correct size of tragal cartilage by placing a piece of thin Silastic onto the cartilage and cutting the superfluous cartilage off, leaving the perichondrium intact. The Silastic has previously been trimmed to the exact size of the scutum defect

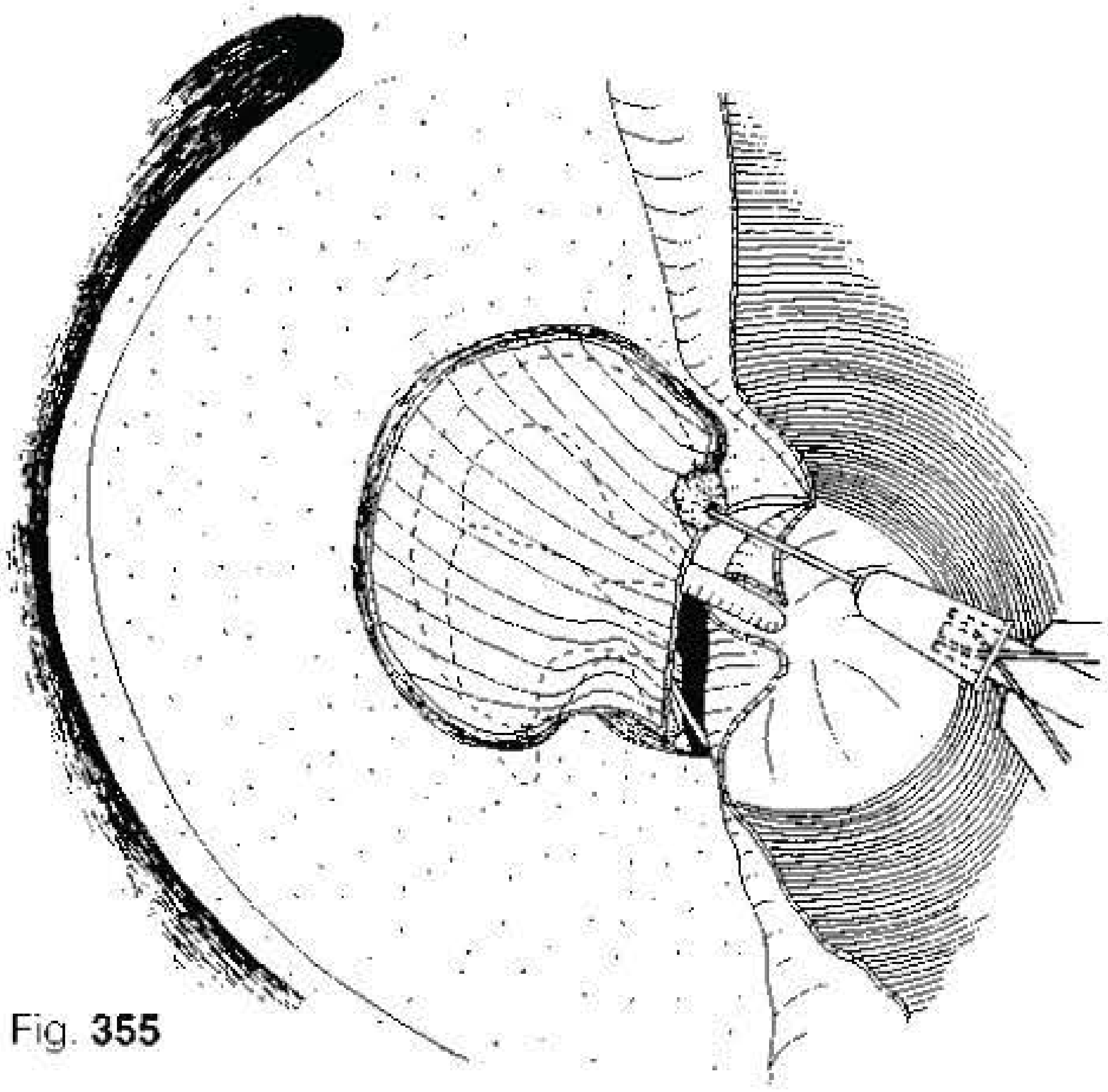


Fig. **355**

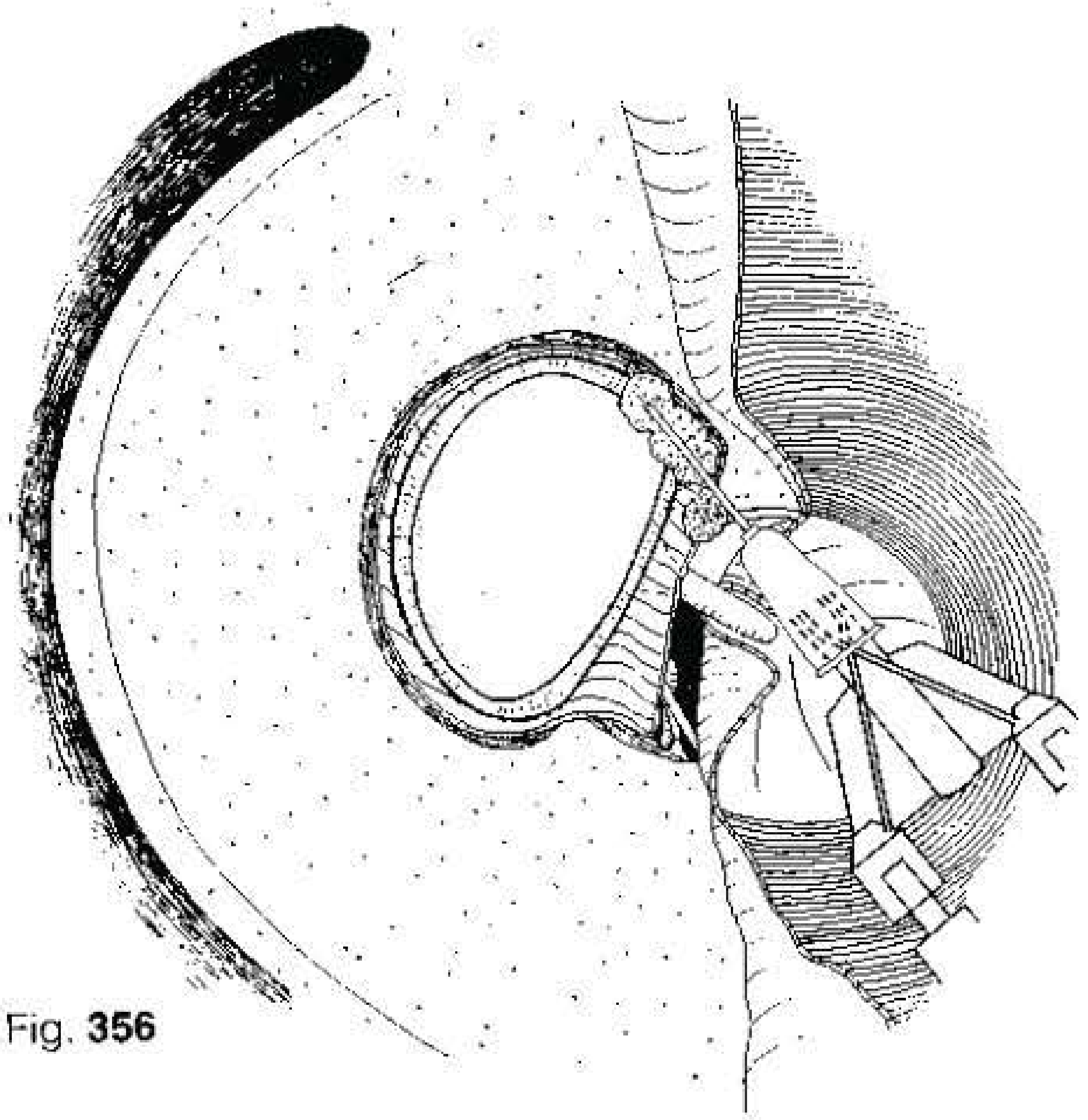


Fig. **356**

Fig. **355** **The Honda scutumplasty method,** using fascia and free tragal cartilage graft. The fascia, trimmed to the exact size of the defect, is placed and glued onto the deepithelialized drum, and adapted to the bony ear canal defect

Fig. **356** The trimmed tragal cartilage is placed on the fascia. It fits the scutum defect exactly, and is glued to the bone with fibrin glue

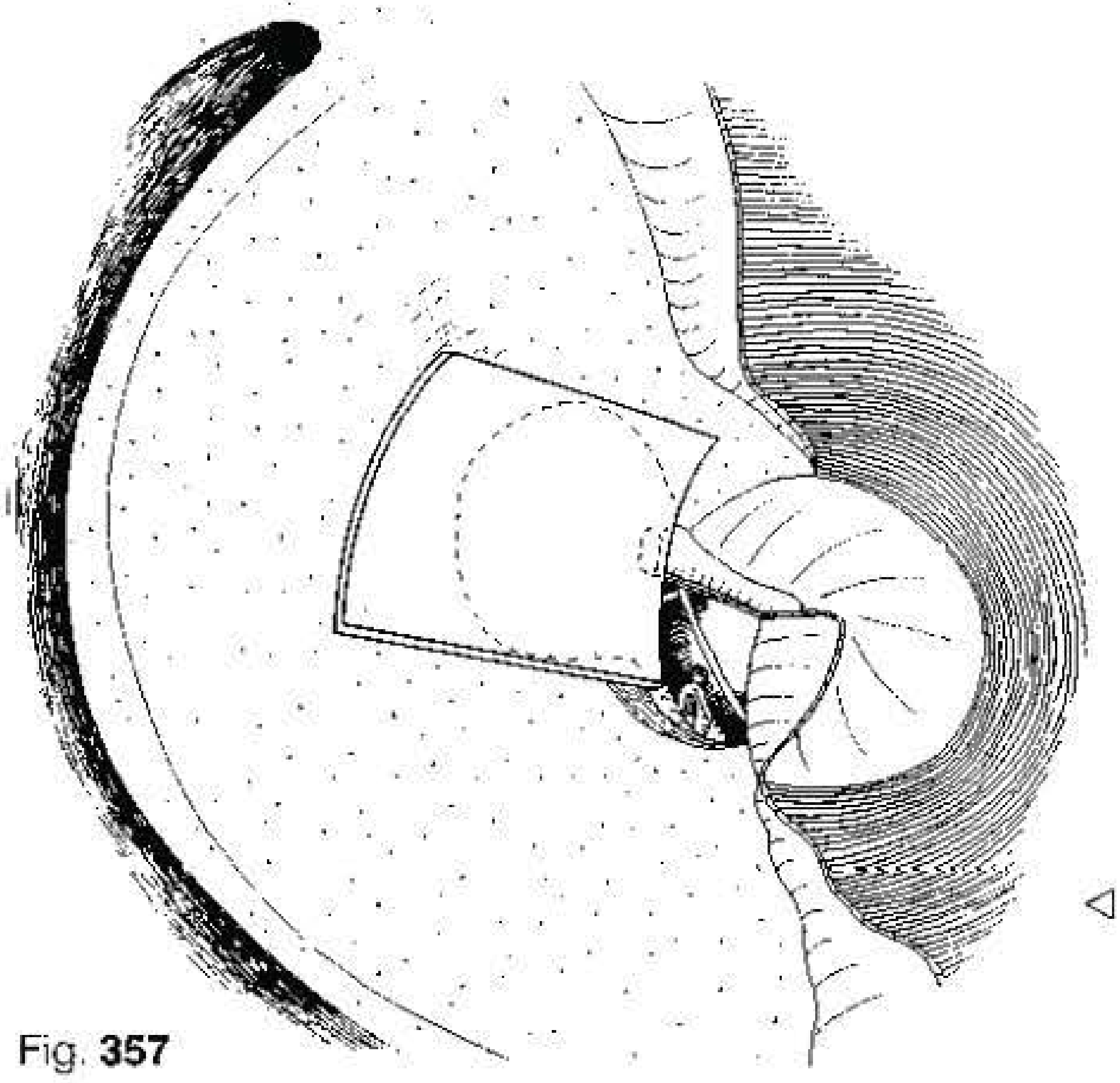


Fig. **357**

◁ Fig. **357** **The Sheehy scutumplasty method,** using a sliced piece of tragal cartilage placed on the meatal side of the bony ear canal wall. The size of the defect is indicated by dashed lines

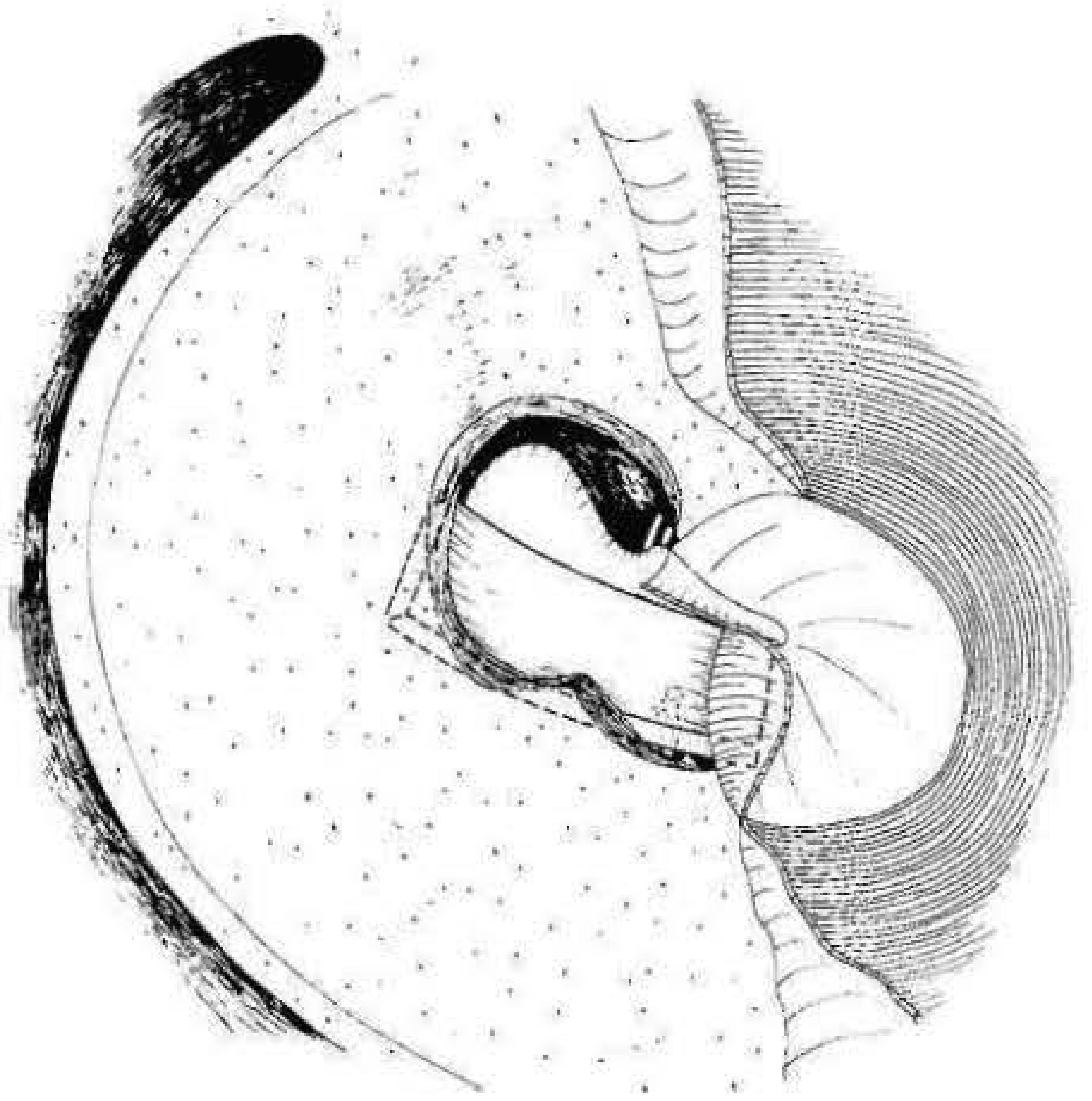


Fig. **358** Placing a large piece of tragal cartilage on the head of the stapes and on the malleus head in order to prevent a retraction into the posterior attic (Sheehy)

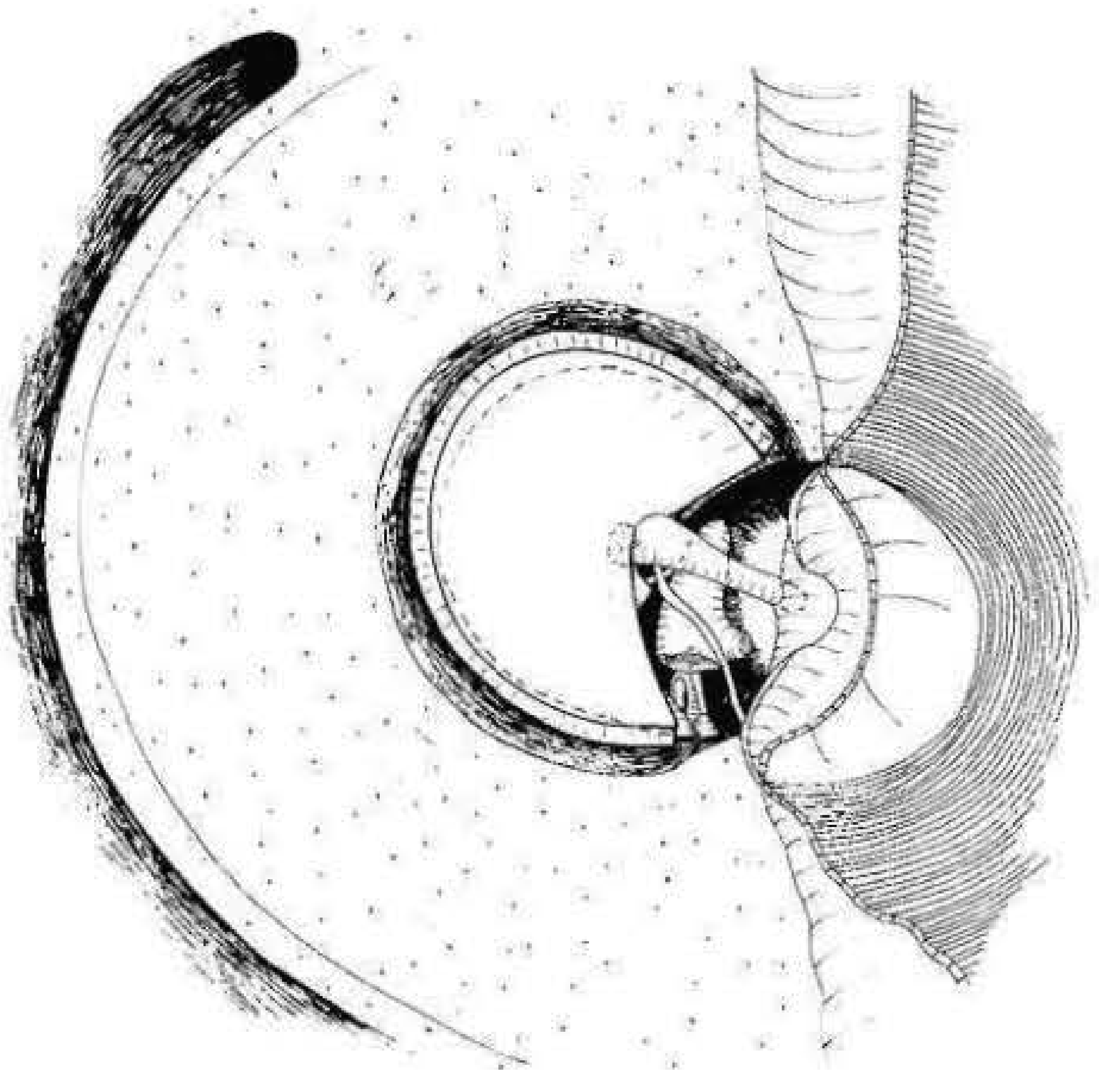


Fig. **359** **Scutumplasty with conchal cartilage.** A large, concave piece of conchal cartilage is placed on the meatal surface of the bony ear canal wall in a situation with a large scutum defect, a resected malleus head, and a type II tympanoplasty

Allogenous Cartilage

Allogenous *septal cartilage* was already used in ossiculoplasty by Jansen (1963), and later by several other surgeons, e. g., Smyth (1980). In scutumplasty, allogenous septal cartilage has been used by Proctor and Proctor (1972), Jansen (1979), and Fisch (1980).

Pappas et al. (1981) reported good late results with a maximum follow-up of eight years when using allogenous septal cartilage in scutumplasty. The cartilage is trimmed to the appropriate size and shape. The shaped cartilage is V-notched on its medial edge (Fig. **360**), i. e., on the convex side parallel grooves every 1–2 mm are made through two-thirds of its thickness in order to increase its flexibility, so that the cartilage will align with the curvature of the defect (Fig. **361**).

Knee cartilage (Wehrs 1972) has a curved, sloping wall and thin edges that almost identically match the posterior bony canal wall. The cartilage is harvested from knees that have previously undergone trauma. The defect in the posterior canal wall is evaluated for size and shape using a piece of compressed Gelfoam, placing the Gelfoam on the meatal side of the defect in the ear canal and pressing it into the defect (Fig. **362a**), producing a template on the Gelfoam. The Gelfoam is trimmed until it precisely fits the defect. It is then placed on the knee cartilage, and the cartilage is trimmed exactly to the size, shape, and curvature of the Gelfoam (Fig. **362b**) and then inserted into the defect (Fig. **363**).

Comparing this procedure with bone and glass ceramics, Bosch (1989) achieved his best results using knee cartilage, with only a 13% retraction rate, apparently because it is easy to adapt and has a curvature similar to that of the meatal wall.

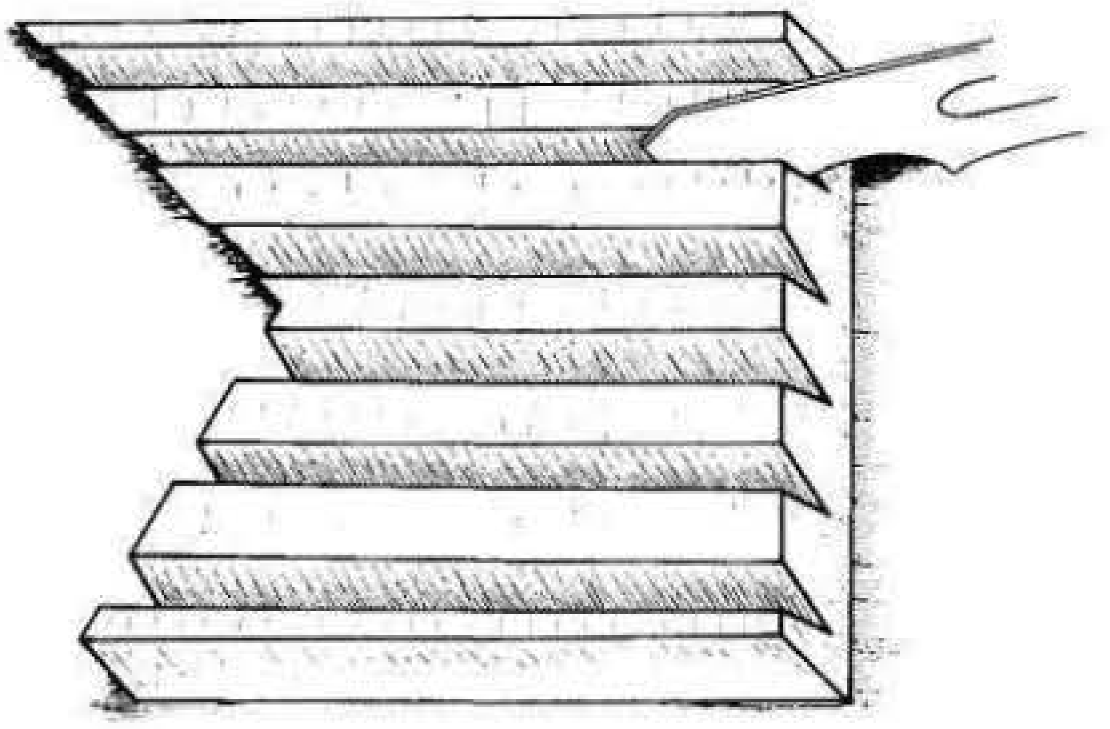


Fig. **360** **The Pappas scutumplasty**, using allogenous septal cartilage. The cartilage is trimmed, V-notched, and several parallel grooves are made on its convex side through two-thirds of its thickness.

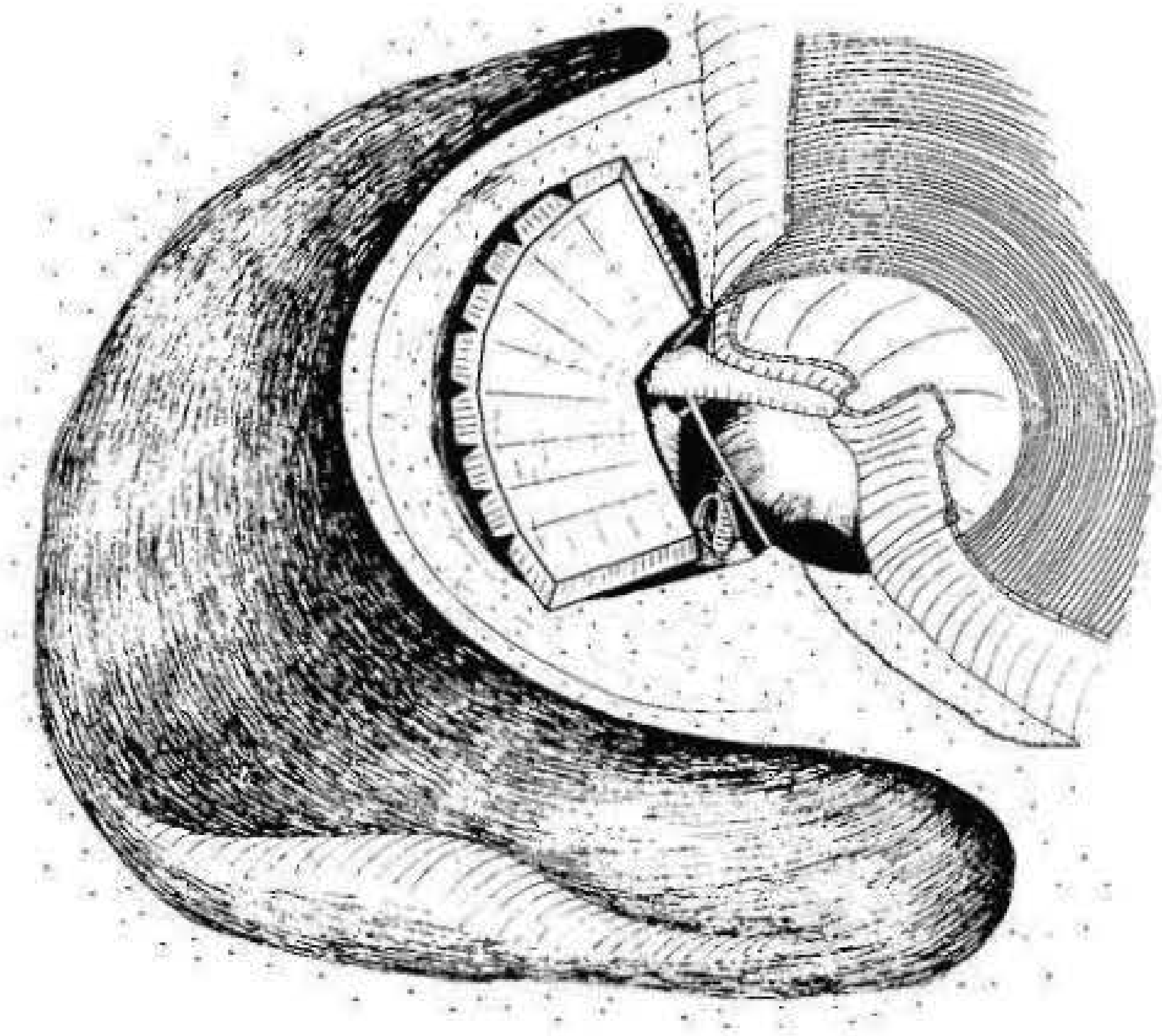


Fig. **361** The allogenous septal cartilage is placed on the meatal side of the bony ear canal wall in a situation with a classic intact canal wall mastoidectomy and a large defect of the scutum and missing incus. The flexible cartilage, with several grooves, aligns with the curvature of the defect and with the ear canal wall

Allogenous **costal cartilage** is suitable for covering scutum defects in slices or as thicker pieces. A 1-cm piece of costal cartilage can be cut into many thin slices, which are easy to place on the meatal side of the bony meatus (Zini 1994).

Scutumplasty with shaped thick costal cartilage plates was introduced by Zini (Maffei and Zini 1972). A 1 mm-thick piece of costal cartilage is cut from the rib. After measurement of the scutum defect with Silastic as described above (Fig. **353**), the exact size of costal cartilage to fill the bony defect is cut, and this piece is surrounded by a rim of thin costal cartilage (Fig. **364b**) to be placed on the meatal side of the bony canal wall. The thick part fills the defect (Fig. **364c**).

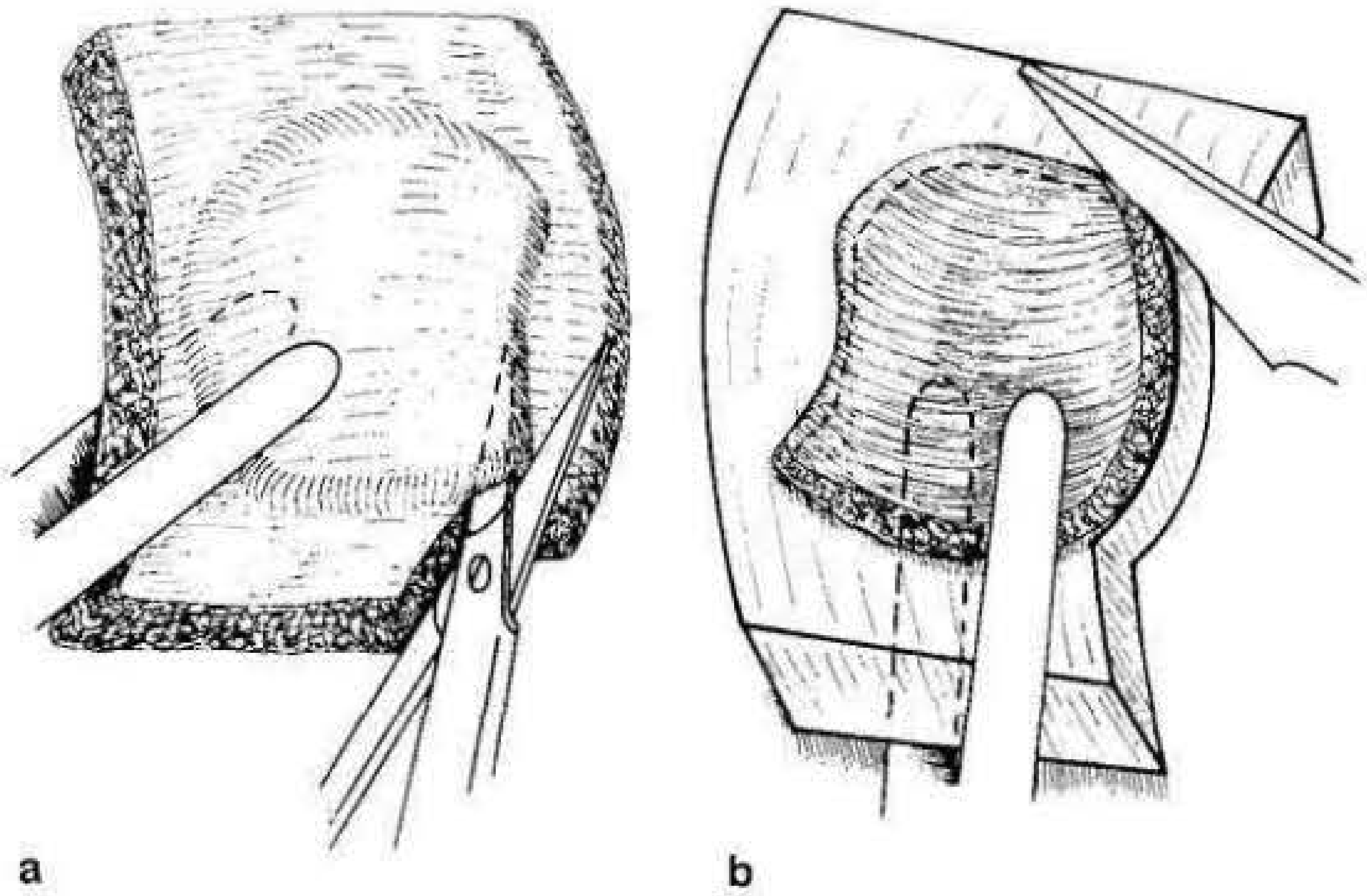
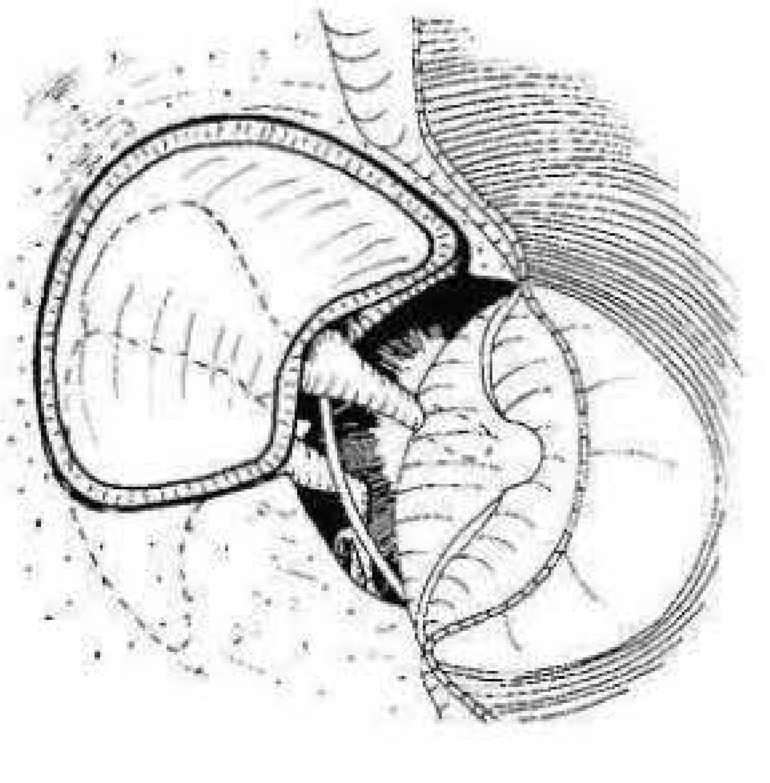


Fig. **362** **The Wehrs scutumplasty,** using knee cartilage.
a A compressed piece of Gelfoam is placed on the meatal side of the ear canal defect and inserted into the defect.
b The Gelfoam is trimmed to the shape of the defect. The trimmed Gelfoam is placed on the knee cartilage, and the correct size of cartilage is cut



◁ Fig. **363** The trimmed knee cartilage, with the exact size and curvature, is inserted into the scutum defect

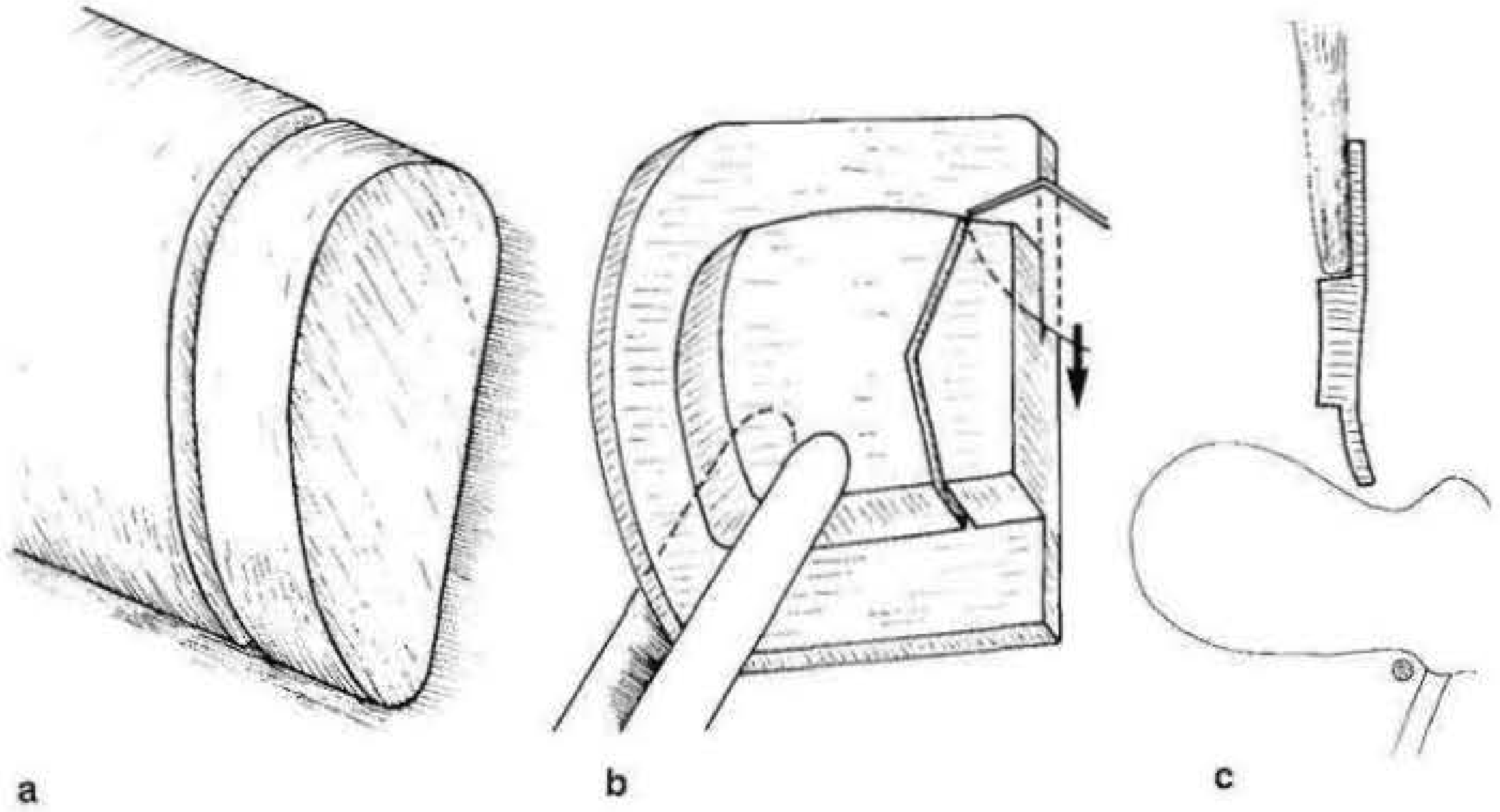


Fig. **364** **The Zini scutumplasty,** using costal cartilage
a A 1 mm-thick piece of costal cartilage is cut.
b The exact size of the thick costal cartilage to be inserted into the bony defect of the scutum is cut and connected to the thin slice of cartilage to be placed on the meatal side of the bony ear canal
c The situation from the side view. The thin part of the costal cartilage lies on the meatal wall and on the malleus head, while the thick part fills the defect

Bone in Scutumplasty

Autogenous orthotopic bone is harvested from the mastoid cortex, and can be used as simple plates or as bony pieces sculpted to the proper size and shape to be placed in the scutum defect after classic intact canal wall mastoidectomy.

Plates of cortical bone have been used by Guilford (1960) and Portmann (1966, 1977).

Gerlach (1979) prefers the periosteum to remain attached to the cortical bone harvested from the mastoid cortex. The periosteum covers the borders between the bony plate and the attic defect, especially in the medial part of the defect (Fig. **365 a**), similar to the arrangement for cartilage-perichondrium compound grafts. For further support of the bone-periosteum compound graft, lyophilized dura has been used (Fig. **365b**).

Pou (1977) advocated the use of a piece of autogenous cortical bone, cut with a thin chisel, which curls into the shape of the attic defect that has been destroyed by the cholesteatoma. The present author, when performing atticotomy with preservation of the bridge and a modification of the intact canal wall mastoidectomy (Chapter 7) has covered the atticotomy opening with variously sized pieces of bone obtained by chiseling with a curved chisel (Fig. **366**), and found that such pieces can be fitted into the attic defect (Fig. **367**). If the bony bridge or a part of it is preserved, the fixation of this type of

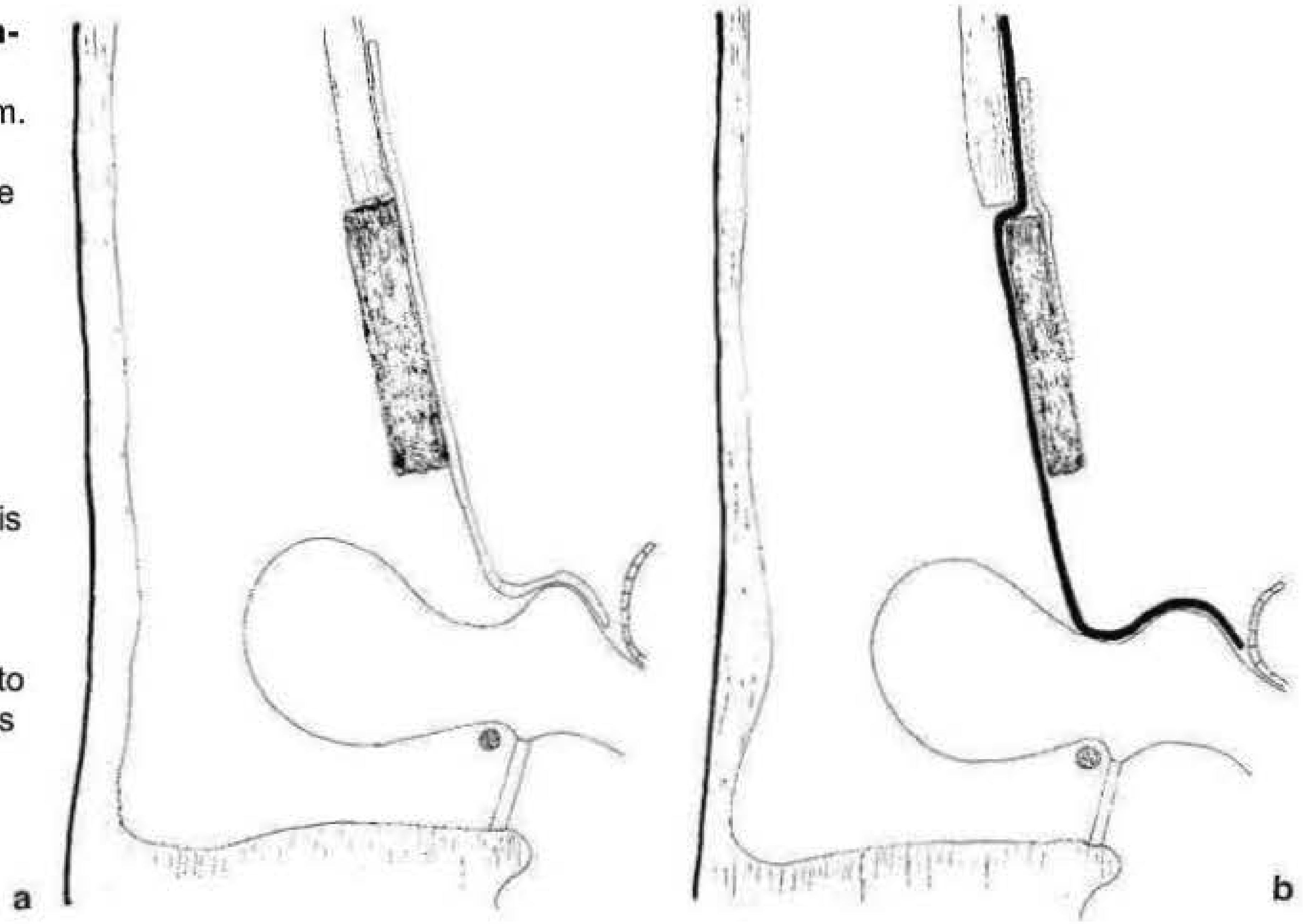


Fig. **365** **The Gerlach scutumplasty method** with a bony plate attached to the periosteum.
a The attached periosteum is placed on the meatal side of the bony ear canal wall and the short process of the malleus. The bony plate covers the defect.
b A bone-periosteum compound graft together with the lyophilized dura (thick line). A large piece of lyophilized dura is placed under the bony plate and the periosteum, covering the bony defect and the entire lateral attic region, attaching it to the short process of the malleus

bone fragment is easier. In cases with no bridge, it is difficult to place a piece of bone on the meatal side of the attic wall or in the defect. The bone has to be shaped in a special way in order to remain in place.

Sakai et al. (1986) have described a method of scutumplasty using shaped autogenous bone, fixed into grooves. Harvesting of cortical bone is performed after completion of the intact canal wall mastoidectomy by drilling, with a small cutting burr, three groves in a 1-cm^2 area of cortical bone at the upper limit of the cavity (Fig. **368**). Grooves to a depth of 0.5–1.0 mm are made, delineating the piece of cortical bone to be harvested. Finally, the bony plate is carefully chiseled and elevated using a flat, broad chisel and a mallet, as applied in rhinoplasty. On the meatal side of the bony ear canal, a 1-mm deep groove is made as anteriorly as possible, to avoid drilling of the already thinned ear canal (Fig. **369**). The posterior groove cannot be deep, because the ear canal is already thin. After fitting the piece of cortical bone to the grooves, and after fashioning it into a concave shape, the bone is placed on the defect (Fig. **370**). The autogenous bone and short process of the malleus are then covered with fascia, and the epithelial flaps are replaced.

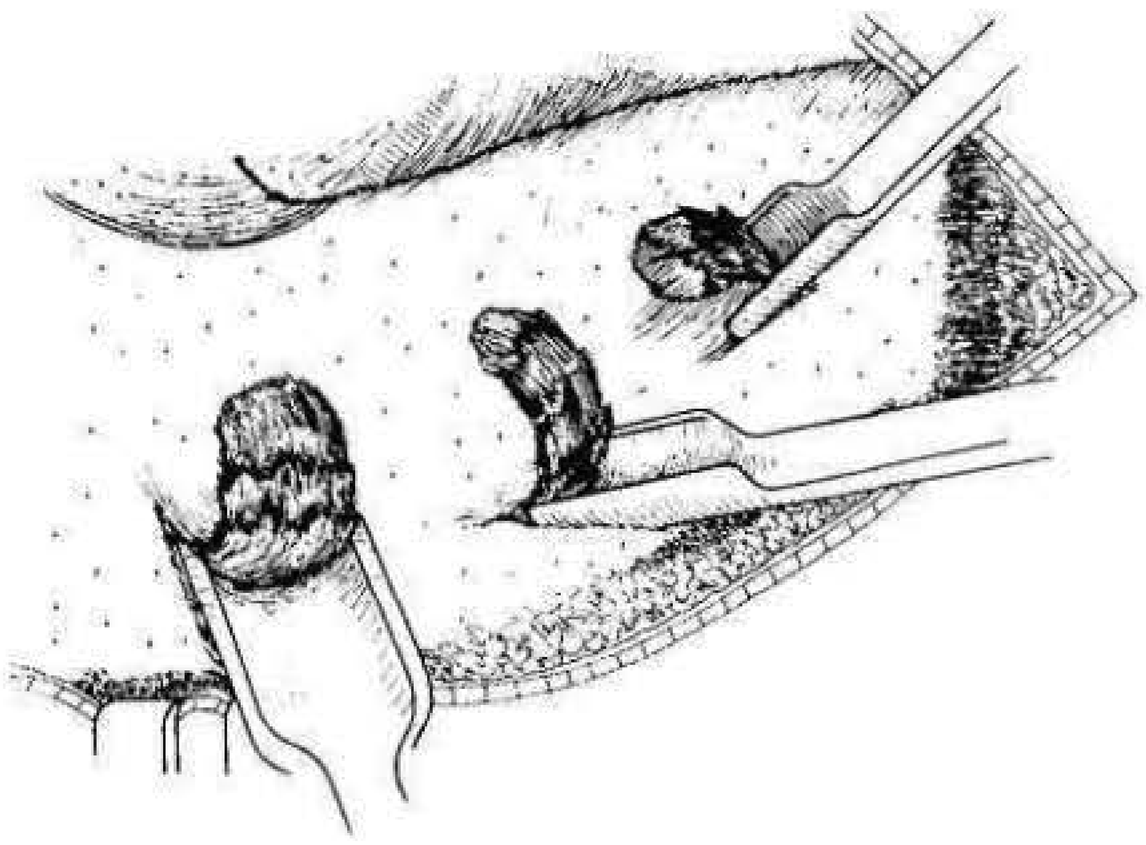


Fig. **366** Various sizes of bone pieces harvested by chiseling the mastoid cortex with a curved chisel. These pieces of bone can be fitted into the attic defects

The following criteria for scutumplasty were applied by Sakai et al. (1989):

- The size of the attic defect should be less than 0.5×0.5 cm.
- A small, well-encapsulated cholesteatoma in the attic.
- Cholesteatoma restricted to the lateral attic and middle ear.
- No destruction of the coverings of the facial nerve or semicircular canal.
- No extensive changes to the mucosal lining within the tympanic cavity.

Using these relatively strict criteria, Sakai et al. (1989) achieved excellent results with this technically difficult method. After more than three years' observation, a 5% rate of retraction cholesteatoma and a 4% rate of dry attic retraction pockets were found.

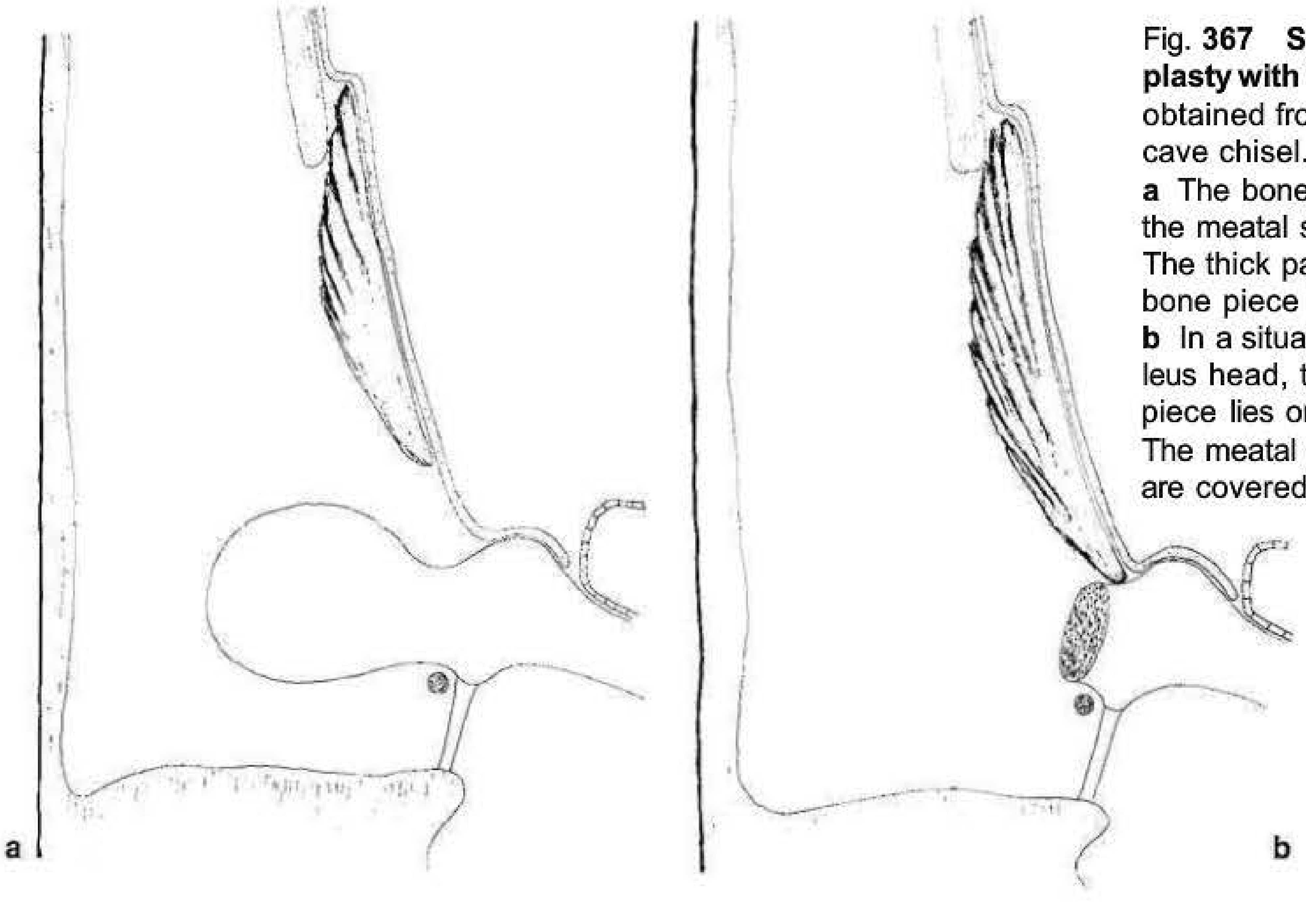


Fig. **367** **Side view of the scutumplasty with "curled" bone pieces** obtained from chiseling with a concave chisel.
a The bone piece is placed partly on the meatal side of the ear canal wall. The thick part fills the defect. The bone piece is covered with fascia.
b In a situation with a missing malleus head, the thin part of the bone piece lies on the neck of the malleus. The meatal wall and the bone piece are covered with fascia

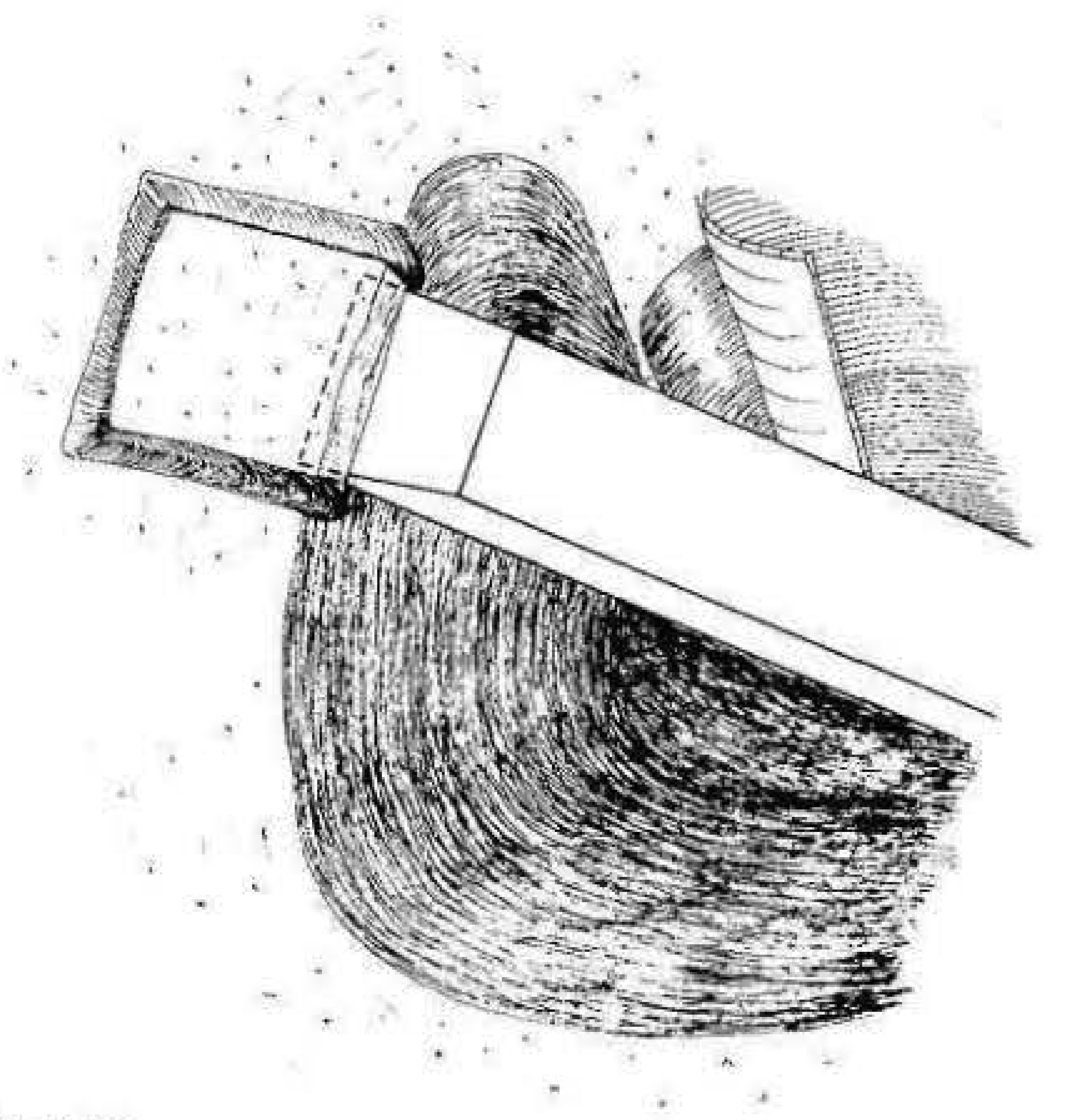


Fig. 368

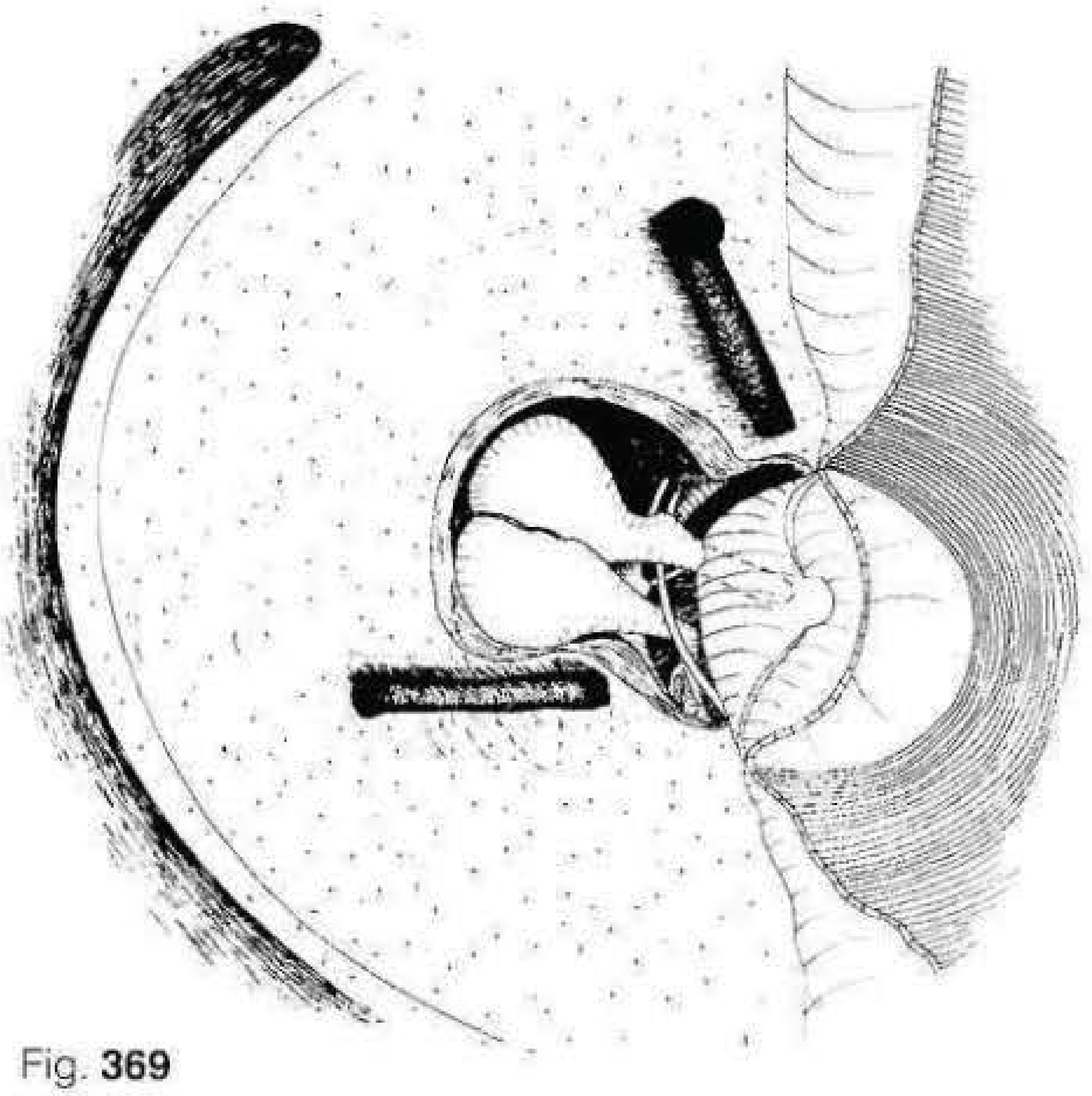


Fig. 369

Fig. 368 **The Sakai method of scutumplasty with a piece of autogenous bone** harvested from the superior edge of the cavity using a chisel after drilling three deep grooves with a small cutting burr

Fig. 369 **The Sakai scutumplasty with bone.** Grooves are made anterior and posterior to the scutum defect. The anterior groove is placed as far anteriorly as possible, and is deeper than the posterior one

Fig. 370 The fitted piece of bone is placed in the grooves, covering the bony defect

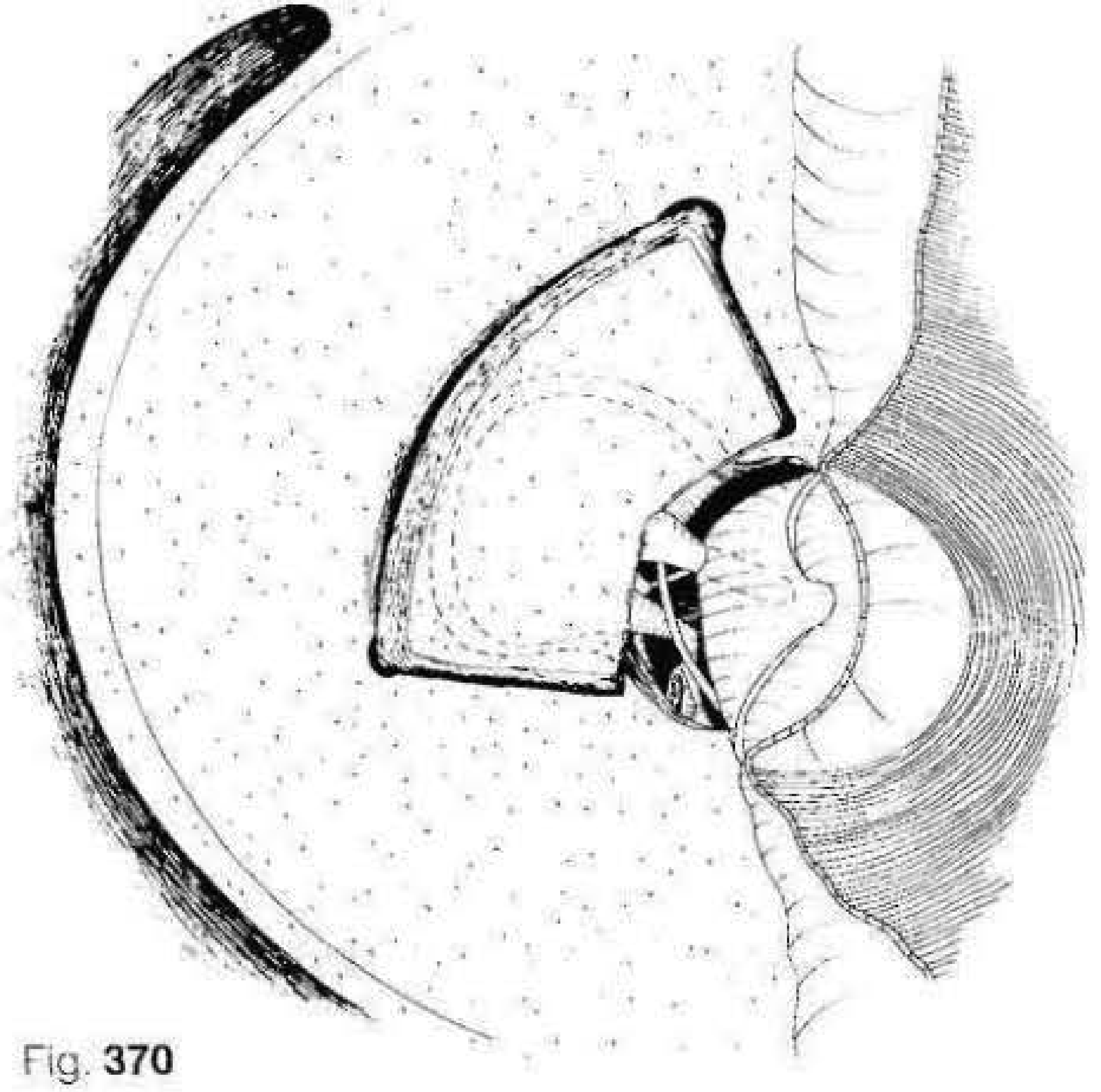


Fig. 370

Scutumplasty Using Autogenous Bone Paté

In the procedure used by Redfield (1989), bone paté is harvested early in the intact canal wall mastoidectomy. After the mastoid surgery and ossiculoplasty are completed, Teflon-reinforced silicone sheeting is used as a stent in the attic. The silicone is inserted into the attic transmastoidally as a folded U-shaped trough, placed behind the defect to facilitate placement of the bone paté in the attic defect (Fig. **371**). The attic region and the remnant of the drum are covered with a relatively thick piece of fascia, and the Teflon–Silastic sheeting is removed.

Bone paté mixed with fibrin glue is used by Robinson (1989) in the repair of attic defects in classic canal wall–up mastoidectomy.

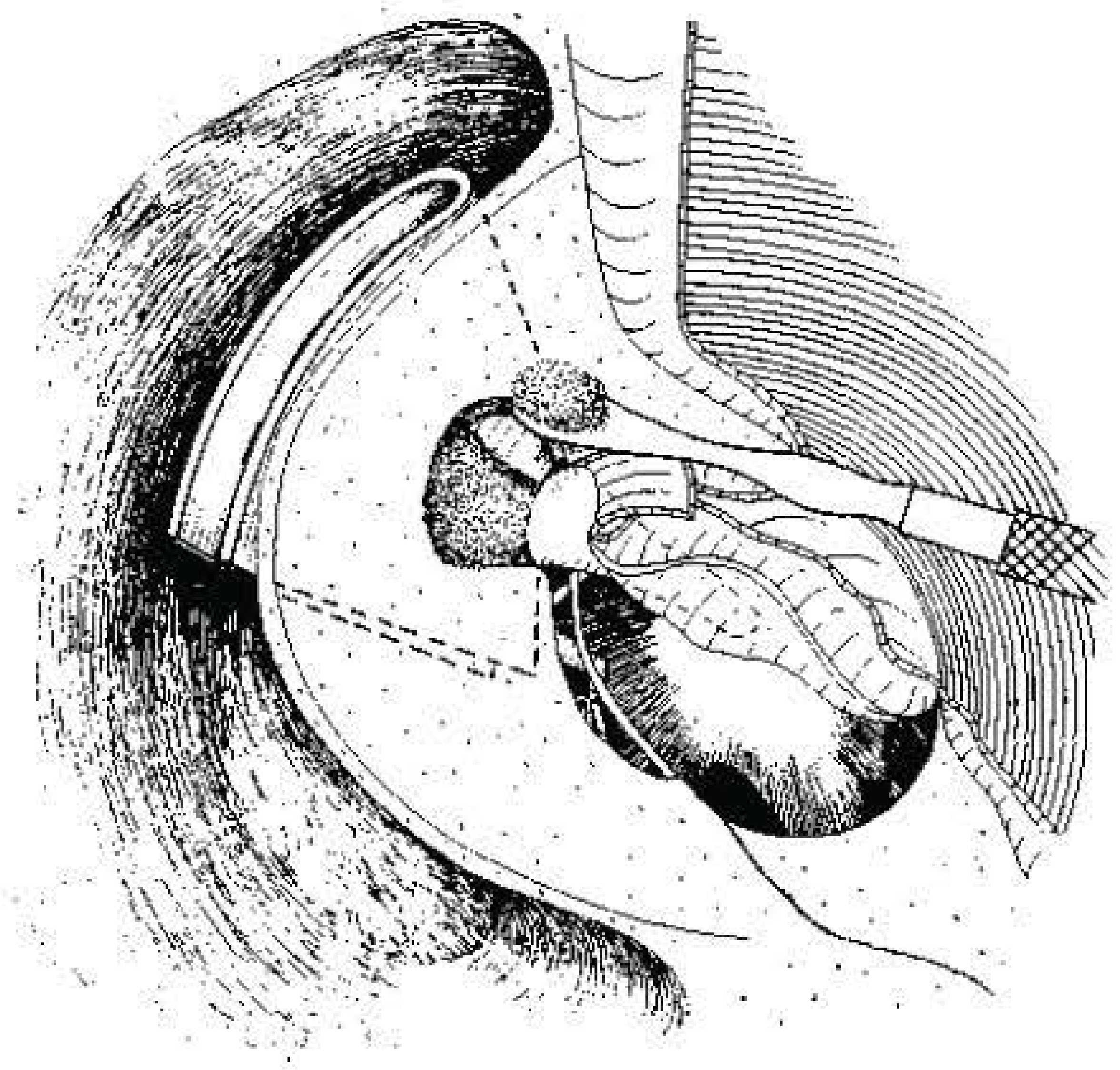


Fig. **371** **The Redfield scutumplasty method,** filling the scutum defect with bone paté in an intact canal wall mastoidectomy. A U-shaped piece of Silastic is placed temporarily in the attic to act as a stent

Scutumplasty with Biocompatible Materials

In atticotomy without mastoidectomy, scutumplasty has been performed using Silastic only (Donald et al. 1974). It is difficult to understand why Silastic should be more efficient than fascia alone.

Hydroxyapatite. Semicircular implants of 7 or 10 mm diameter have been used to close the attic defect in intact canal wall mastoidectomy by Black (Black and Lomas 1991, Black 1992). After intact canal wall mastoidectomy, the mastoid surface of the intact ear canal wall is polished with a diamond burr, particular care being taken in the region of the roof and the lateral wall. The edges of the attic wall are thinned by a transcanal approach. The implant size is selected according to the extent of the defect, ensuring a generous overlap around all the edges of the defect (Fig. **372**). The hydroxyapatite plate is moistened with blood and placed on the mastoid aspect of the ear canal wall (underlay position). The implant is then supported from behind using an elongated U-shaped piece (12×6 mm) of 0.5-mm thick Silastic (Fig. **372 a**). The Silastic is doubled over its long axis. When released from the inserting forceps, the Silastic opens out with sufficient support to maintain the implant firmly in position.

Once the plate is fixed in position, the bone paté, collected earlier, is used to fill the sides of the defect via the transmeatal route (Fig. **373**). The paste also covers the bone of the ear canal adjacent to the defect. The hydroxyapatite plate thus not only covers the scutum defect, but also acts as a per-

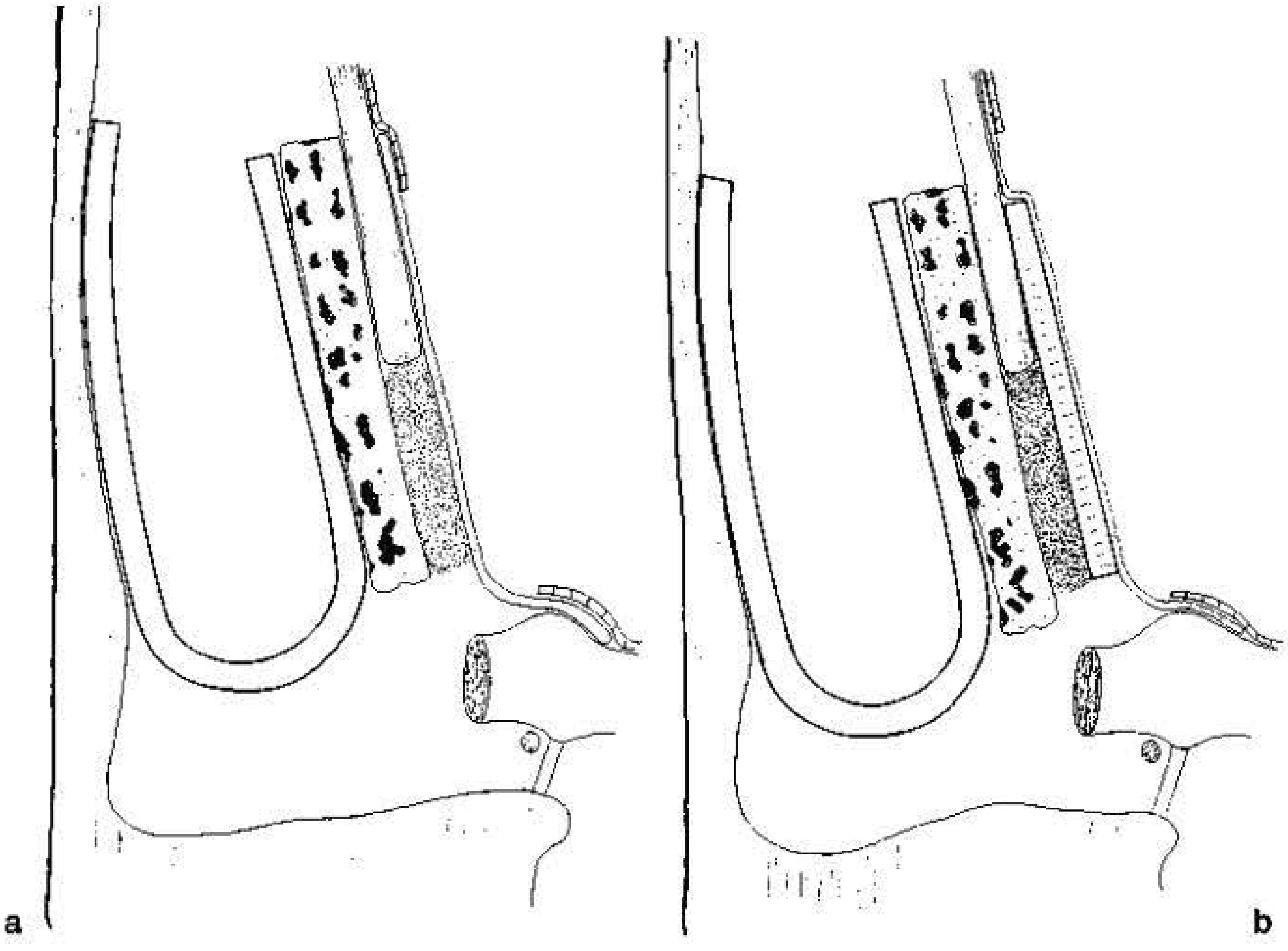


Fig. **372** **The Black scutumplasty method,** using a hydroxyapatite plate.
a The plate is placed on the mastoidal side of the ear canal and held in place with a 0.5 mm–thick piece of Silastic. The scutum defect anterior to the plate is filled with bone paté. The ear canal is covered by fascia.
b Further covering of bone paté with a thin cartilage–perichondrium composite graft

manent support for obliteration of the scutum defect with bone paté. The bone paté is covered with canal skin, fascia, perichondrium, or with a thinned composite tragal perichondrium–cartilage graft (Fig. **372b**).

During the planned second-stage operation, the Silastic is removed, and the attic is inspected for disease. The hydroxyapatite plate may be thinned using a diamond burr to permit better visualization of the anterior attic, if required.

Postoperative Attic Retraction

Besides residual cholesteatoma that may be hidden in the mastoid cavity or attic, the other major problem in classic intact canal wall mastoidectomy is attic retraction.

Causes of Retraction

The following factors are associated with retraction (Fig. **374**).

1. **Dysfunction of the Eustachian tube,** which is both common and more severe in ears with cholesteatoma and adhesive otitis compared with other noncholesteatomatous chronic middle ear diseases (Tos 1974 c, Bluestone et al. 1977, Bluestone et al. 1978, Tos 1979 b, Tos 1980 b, Chan et al. 1989, Falk and Magnusson 1989, Sato et al. 1989).

Peroperative management of the Eustachian tube (Tos 1974 c, Tos 1980 b, Zini et al. 1989), including placement of a ventilating tube, can be effective and helpful in some cases. Postoperative ventilation with Valsalva's maneuver, or insufflation using a balloon, is important.

2. **Lack of communication between the Eustachian tube and the antrum/aditus** due to pathology or surgery. It is important to create a stable connection between the attic and the epitympanic sinus and supratubal recess (Morimitsu et al. 1989, Morimitsu 1991). The adhesions and folds in the attic should carefully be removed, without removing any of the underlying mucosa. The anterior attic bony plate—the cog—has to be removed in such a way that most of the mucosa lining the connection between the Eustachian tube and the attic is preserved. In the present author's opinion, nothing but air should remain in the attic at the end of the surgery if repneumatization of the cavity is desired. Gelfoam and blood must be eliminated; if not, they will in the long term create a foreign-body reaction causing granulations, adhesions, and obstruction. Gelfoam and bleeding must also be avoided in the mastoid cavity, and the cavity should already be ventilated during the early postoperative days. In order to drain blood and fluid during the first few postoperative days, we place a thick ventilating tube in the mastoid cavity (see Chapter 7) and remove it after three weeks. In a positive Valsalva's maneuver, air passes through the ventilating tube, and is a good prognostic sign for successful repneumatization.

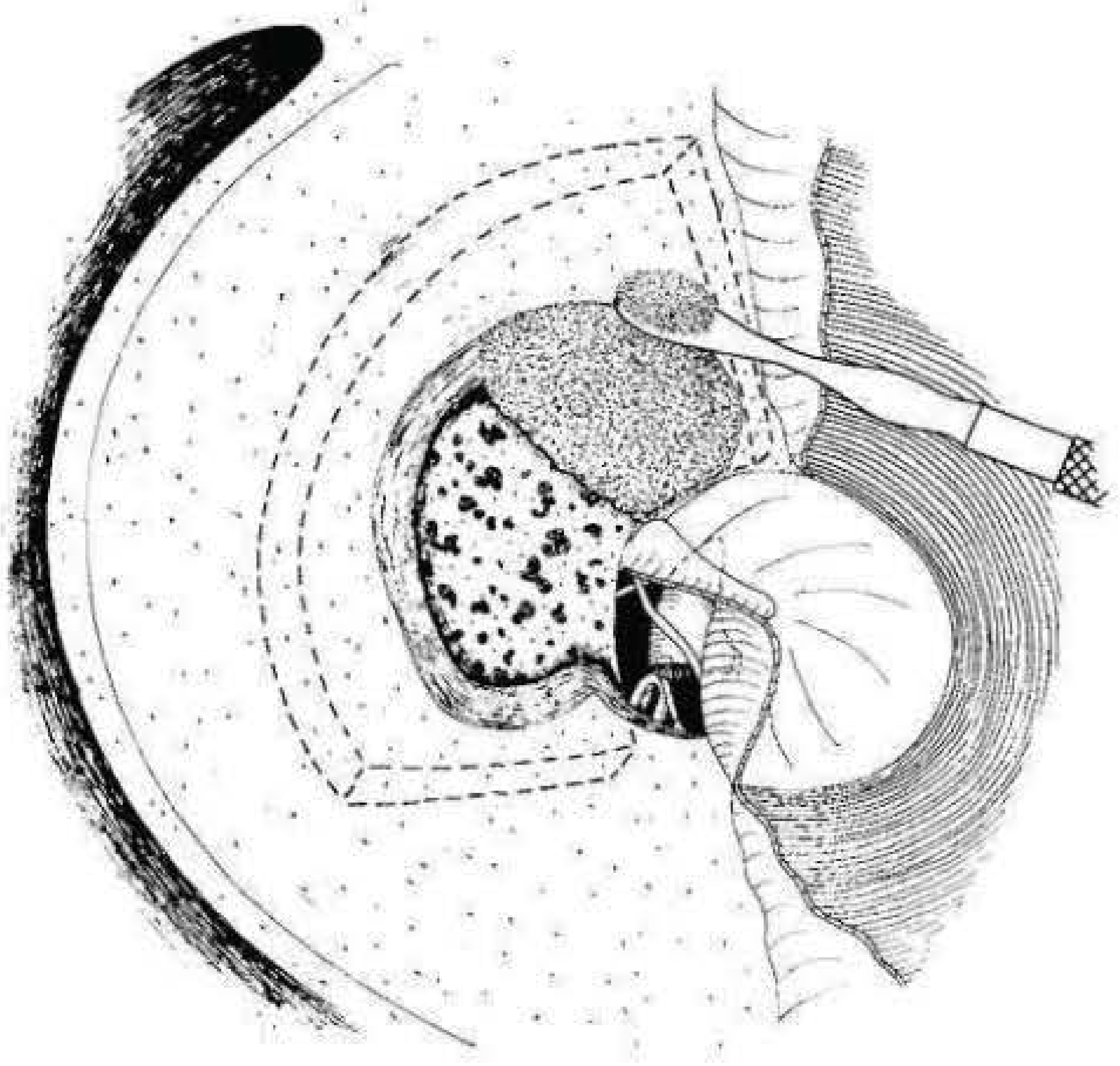


Fig. **373** The hydroxyapatite plate in place behind the ear canal. The defect is filled with bone paté

3. **Chronic inflammation in the attic,** usually as a result of accumulation of material coming from the mastoid cavity into the attic. The attic is the narrowest space in the middle ear cleft apart from the Eustachian tube, and removal of the attic mucosa leads to an inflammatory reaction in this region. This can be due to accumulation of material in the attic that cannot be transported away to the Eustachian tube, such as blood clot, bone dust, mucus, serous fluid, etc. Especially important is the presence of mucosa in the tympanic isthmus, representing the most important pathway of ventilation (Wullstein and Wullstein 1990, Miyama and Honda 1986, Proctor 1989). Preservation of an intact ossicular chain, or even the malleus head, protects the tympanic isthmus.

4. **Defects of the attic wall** often lead to retraction, which is more easily recognizable, and appears earlier, than in ears with no defect of the attic wall, or in those with a perfectly reconstructed scutum. Creating a thick drum, e. g., with cartilage and two layers of fascia to prevent retraction, to some degree solves the problem, but it results in considerable

hearing loss, and then it is also impossible to detect any residual cholesteatoma in the tympanic cavity.

Two-stage surgery, which is popular in centers advocating classic intact canal wall surgery for cholesteatoma, to some extent eliminates some of the postoperative sequelae mentioned above, such as retracted membranes or retracted scutum repair material (cartilage or bone), but excessive surgery in the attic at the second stage will result in further damage to the mucosa and new adhesions, with new problems of ventilation through the attic and tympanic isthmus. Using Silastic sheeting, with large, thin sheets continuing from the tympanic cavity through the attic to the mastoid cavity, does not solve the problem of adhesions. The attic mucosa on both sides of the Silastic sometimes thickens, causing severe stenosis with very little ventilation. The problems associated with Silastic sheeting and two-stage surgery are analyzed in Volume 3.

Mechanisms of Retraction

There are at least three clear mechanisms in the formation of attic retraction.

1. **Pocketing caused by negative pressure.** Impaired tubal function, or impaired ventilation of the attic through the tympanic isthmus, creates negative pressure in the cavities. The mechanism is the same as that in tubal occlusion, causing resorption of the gases in the middle ear and negative pressure and retraction in the attic at the same time the drum is retracted (Figs. **374a** and **b**). On reaching the attic

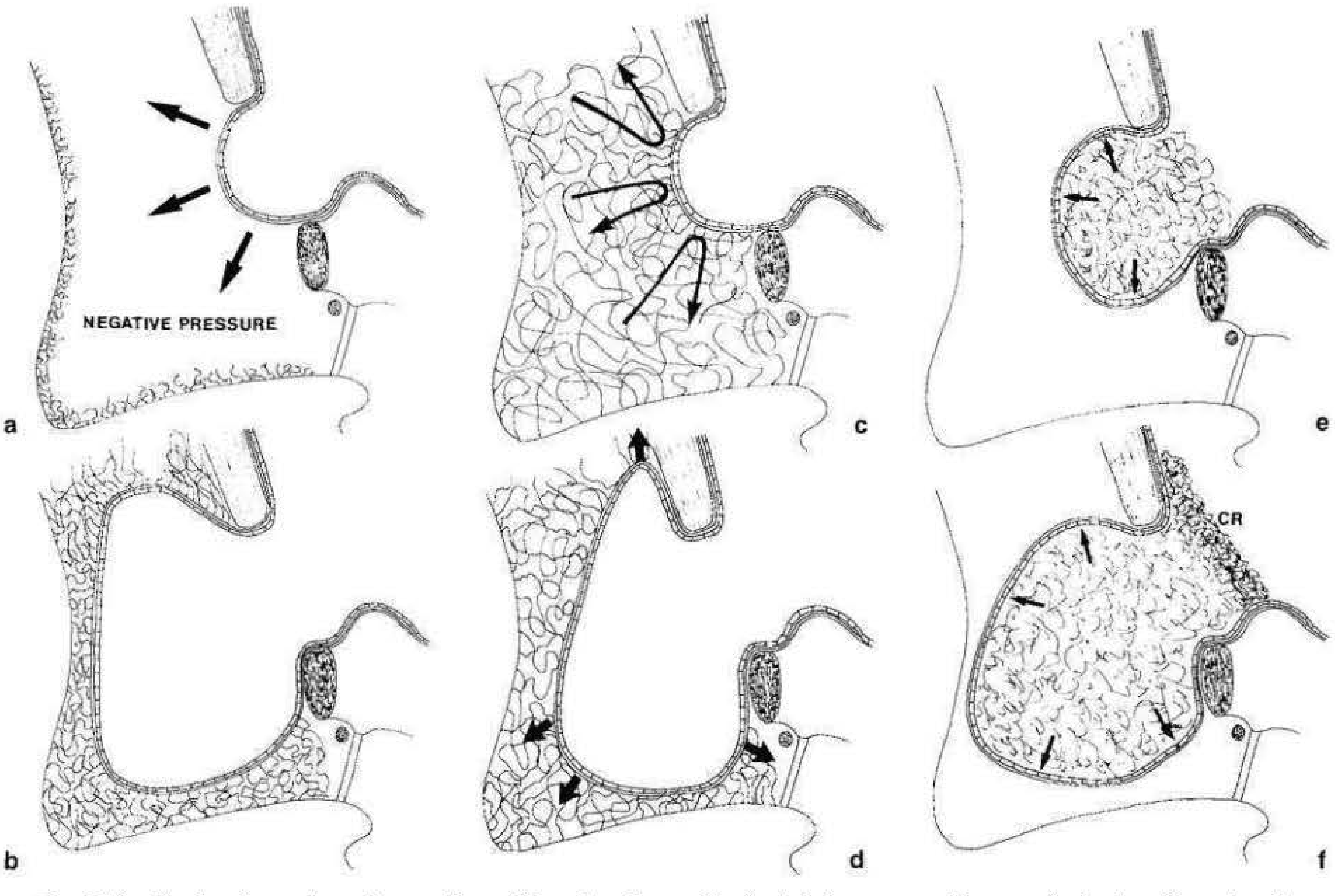


Fig. **374** **Mechanism of postoperative attic retractions,** illustrated in cases with an extruded malleus head, an empty attic, and slight resorption of the bony ear canal wall.

a **Reduced pressure** in the middle ear, including the attic, pulls the soft ear canal wall into the attic.

b The retraction is further enlarged; the membrane is touching the attic wall and is adherent to it.

c **Formation of granulations** in the attic, filling out all the attic and touching the soft wall of the ear canal and adhering to it.

d After regression of the granulations and the fibrous tissue toward the attic wall, the soft ear canal is pulled inside the attic.

e **The retraction is initially pressed into the attic** by incorrect packing or accumulation of debris within the retraction.

f Further expansion of the retraction, which fills with debris and has its access closed by a crust (CR) walls, the retracted membrane may adhere to the walls, leading to a permanent condition.

2. **Traction by adhesions.** Excessive formation of granulations and adhesions in the attic (Fig. **374c**) may reach the fascia and grow together with it. During the healing process, the adhesions attached to the drum or the soft ear canal pull the soft walls further into the empty cavity (Fig. **374d**). The retraction is fixed from the very beginning, but usually progresses slowly during the first two postoperative years.

3. **Expansion of the retraction.** A retraction may start with excess pressure within the ear canal caused by inappropriate and excessive packing (Fig. **374e**). Later on, the retraction may expand due to the accumulation of keratin and desquamated epithelium caused by impaired migration from the retraction pocket. Usually, a crust forms at the entrance to the retraction pocket (Fig. **374f**). Beneath the crust, a limited infection within the retraction pocket takes place, increasing the expansion of the retraction. This type of expansion leads to an attic retraction cholesteatoma.

4. **Combination of traction and expansion.** Usually, all three causative factors and mechanisms are found. In some cases, the negative pressure is the major factor, while in others it is granulation tissue formation and adhesions, and in others still, impaired migration.

Appearance and Progression of Retraction

A retraction pocket may occur with a totally intact ear canal wall (Fig. **375a**) in the region of Shrapnell's membrane. The cause may be negative pressure or traction caused by the formation of adhesions in the lateral attic. In cases with an *intact ossicular chain,* the retraction does not usually progress and may be harmless, but if it progresses, especially due to impaired migration out of the retraction, then it can progress within the large empty space and soon becomes unstable and expands into the attic.

In cases with some resorption of the scutum (Fig. **375b**), the retraction may be directed onto the malleus neck and head and may remain stable there, but it can also progress.

In cases with an intact ossicular chain and more extensive resorption of the scutum without a firm scutumplasty, the retraction may be directed onto the malleus head and remain stable, but it can continue toward the tegmen and behind the bony ear canal wall, which may become further resorbed giving the retraction pocket a larger neck (Fig. **376a**). In a case with excessive resorption of the scutum without scutumplasty, a large retraction pocket may occur, but if the neck of the pocket is large enough, the retraction pocket does not necessarily lead to a retraction cholesteatoma provided that regular cleansing with the otomicroscope can be carried out over the long term (Fig. **376b**).

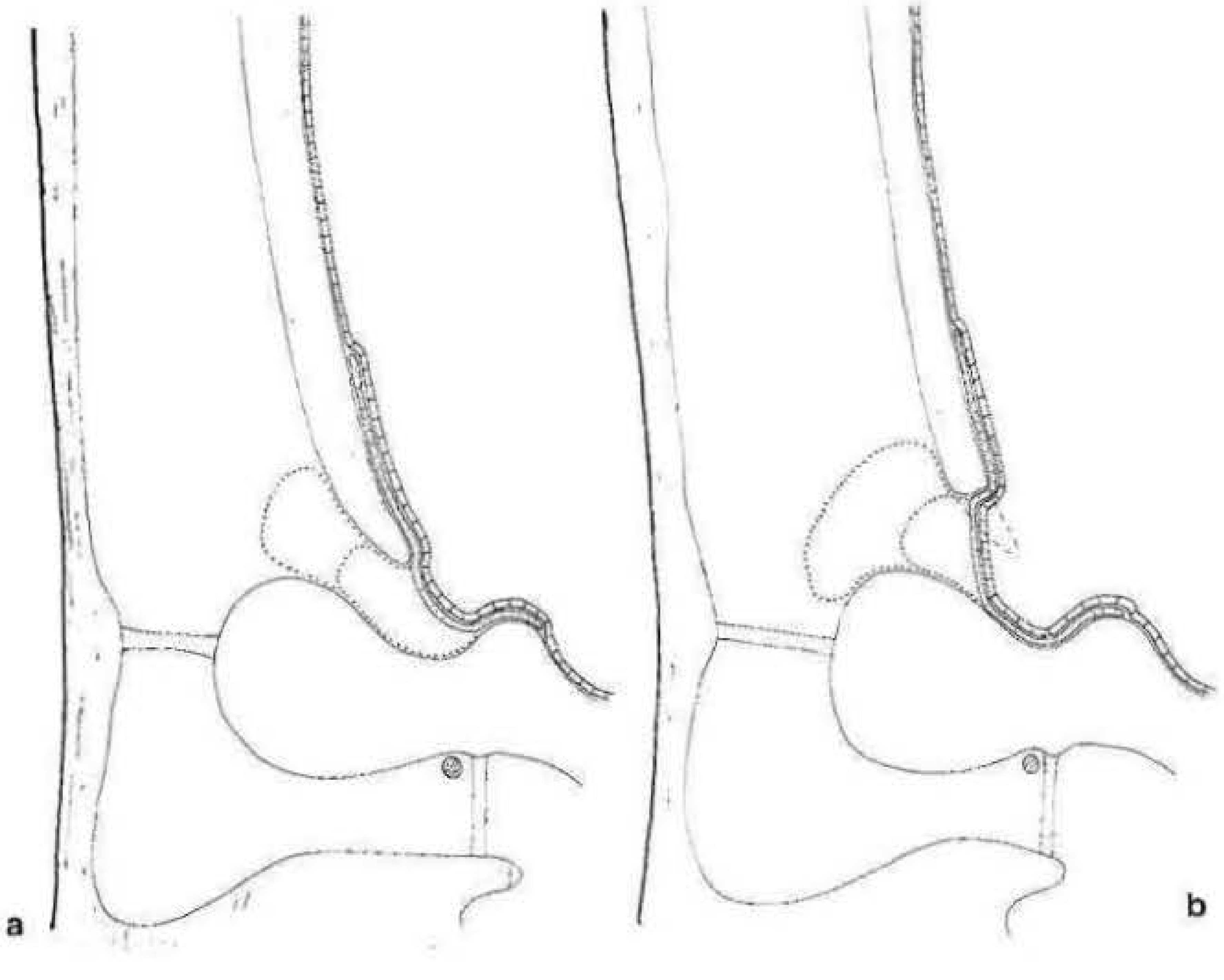


Fig. **375** **Examples of retraction in classic intact canal wall mastoidectomy with the malleus head in situ.**
a Normal scutum. The attic retraction (dotted area) may stop at the malleus head, but it may sometimes progress into the attic.
b Minor resorption of the scutum. The retraction may adhere to the malleus head, with wide access, or may continue into the attic (dotted area)

In cases with an intact ossicular chain and a relatively large scutum defect reconstructed with cartilage and perichondrium, the cartilage can be placed on the neck of the malleus (Fig. **377 a**). Such reconstructions appear to be stable, and potential retraction is restricted between the malleus and the cartilage. On the other hand, retraction can take place at the lateral edge of the cartilage, displacing it into the cavity. With firm reconstruction of the scutum using cartilage or bone, retraction can appear between the medial edge of the new scutum and the neck of the malleus in the same way as described above for normal scutum (Fig. **377b**).

It is obvious that the presence of the incus body and malleus head can prevent some retraction pockets from becoming deeper, because the retraction may stop and adhere to the malleus head. It is worthwhile trying to preserve the malleus head intact and mobile.

In cases with a *missing malleus head,* the attic is empty, and an initial retraction usually progresses, becoming deeper, and may lead to complete closure of the attic and result in a retraction cholesteatoma. Even with a completely intact scutum, retraction between the short process of the malleus and the bony annulus (Fig. **378 a**) can lead to deep and unsafe retraction, which progresses. In cases with more extensive spontaneous resorption (Fig. **378 b**), retraction definitely develops either due to negative pressure or granulation and scar formation. Resorption of the ear canal wall, resulting in a retraction pocket with a large neck or an open atticoantrotomy, may provide a good solution to this problem.

Even with perfect reconstruction of the scutum using bone or cartilage, retraction may occur between the lower edge of the newly reconstructed scutum and the neck of the malleus, leading to a deep retraction pocket (Fig. **379 a**). Another possibility is the displacement of the reconstruction material (cartilage or bone) posteriorly into the empty cavity (Fig. **379 b**).

In a case with *no ossicles* at all, the drum is usually situated closer to the facial prominence and the cochleariform process, and may adhere at these pockets. Retraction onto the medial wall of the attic presumably occurs even with a perfect scutumplasty.

There is a weak point between the lower edge of the scutum and the drum when no malleus handle is present, resulting in a high risk of retraction (Fig. **380 a**). With a large defect in the scutum, which is not reconstructed, as is probably best in such a situation, a large retraction pocket occurs that has a large neck. This type of retraction may be safe, and can be cleaned without fear of any hidden cholesteatoma. The situation resembles an open atticoantrotomy (Fig. **380 b**).

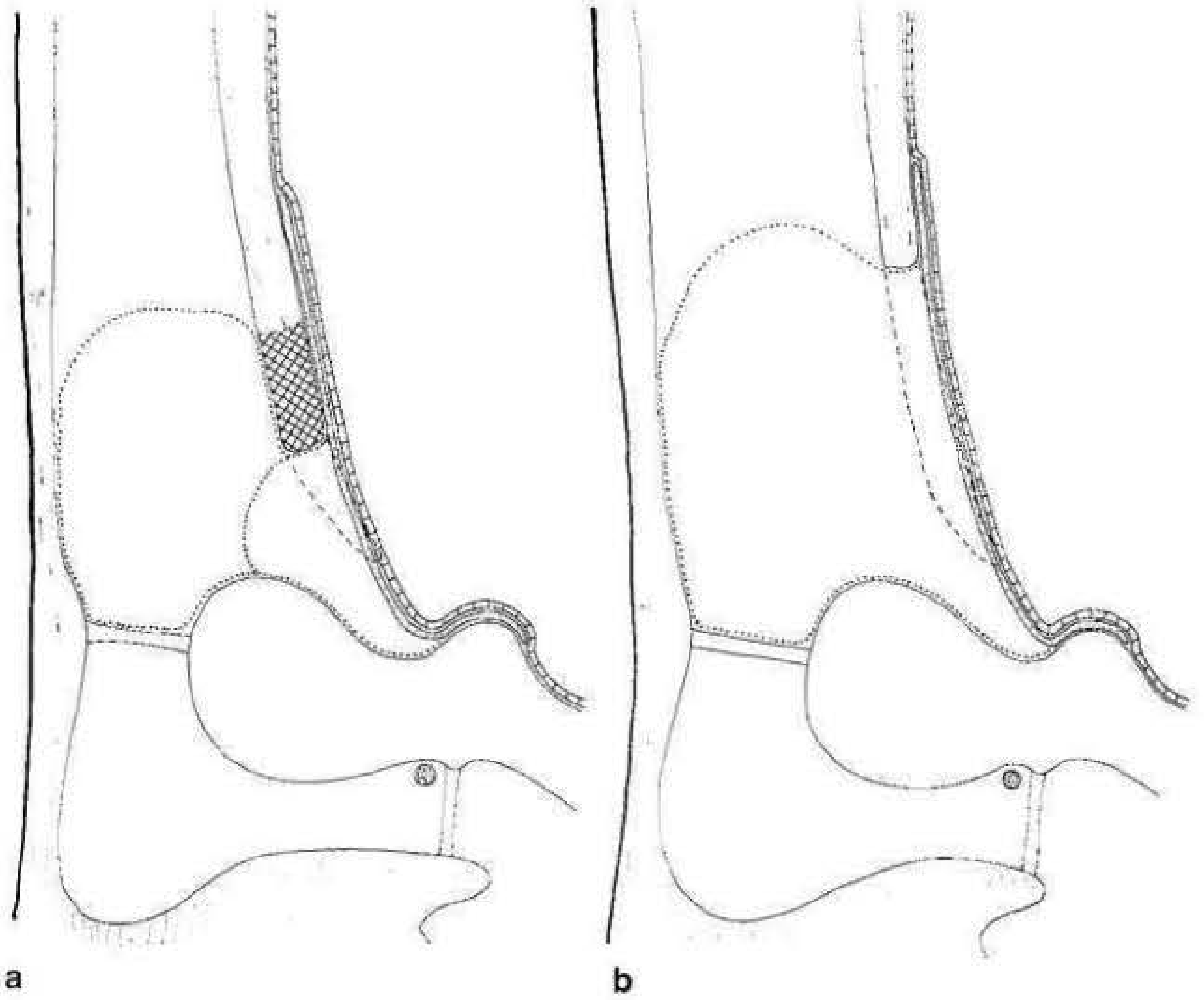


Fig. 376 **Examples of retractions after classic intact canal wall mastoidectomy with some resorption of the scutum.**
a The retraction is primarily onto the malleus head, and may continue into the attic and cause resorption of the bony ear canal (dotted area).
b Extensive resorption of the scutum, reconstructed only with soft tissue. A large retraction will occur, with a large access and good chances of control and cleaning

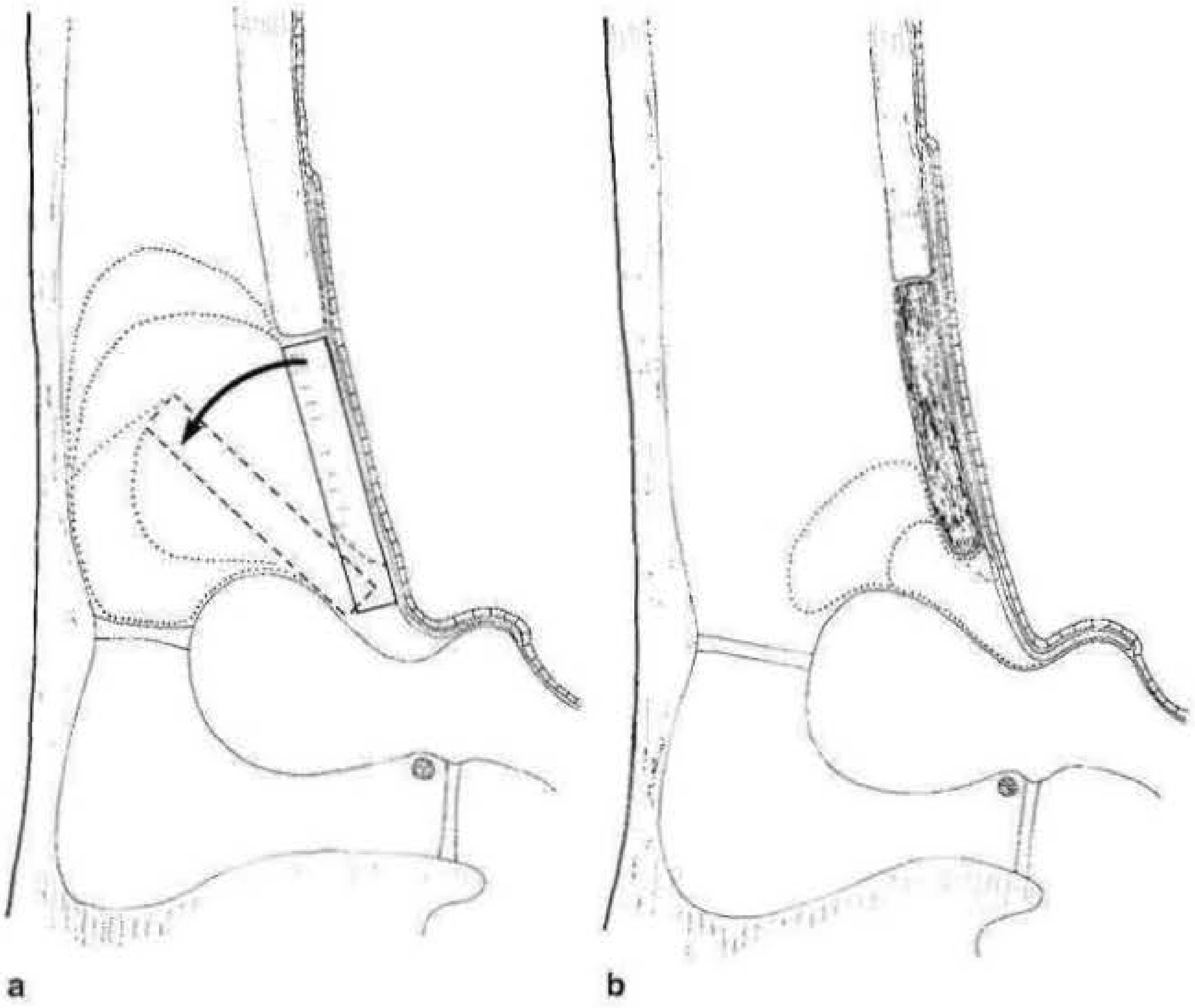


Fig. 377 Examples of retractions after intact canal wall mastoidectomy with a large defect in the scutum.
a Reconstructed with a cartilage–perichondrium compound graft. The cartilage is placed on the malleus head, and can hardly retract here, but it can retract at its lateral end, and the retraction will displace it.
b The scutum defect is covered with bone and fascia. Retraction may occur between the medial edge of the bone and the malleus head

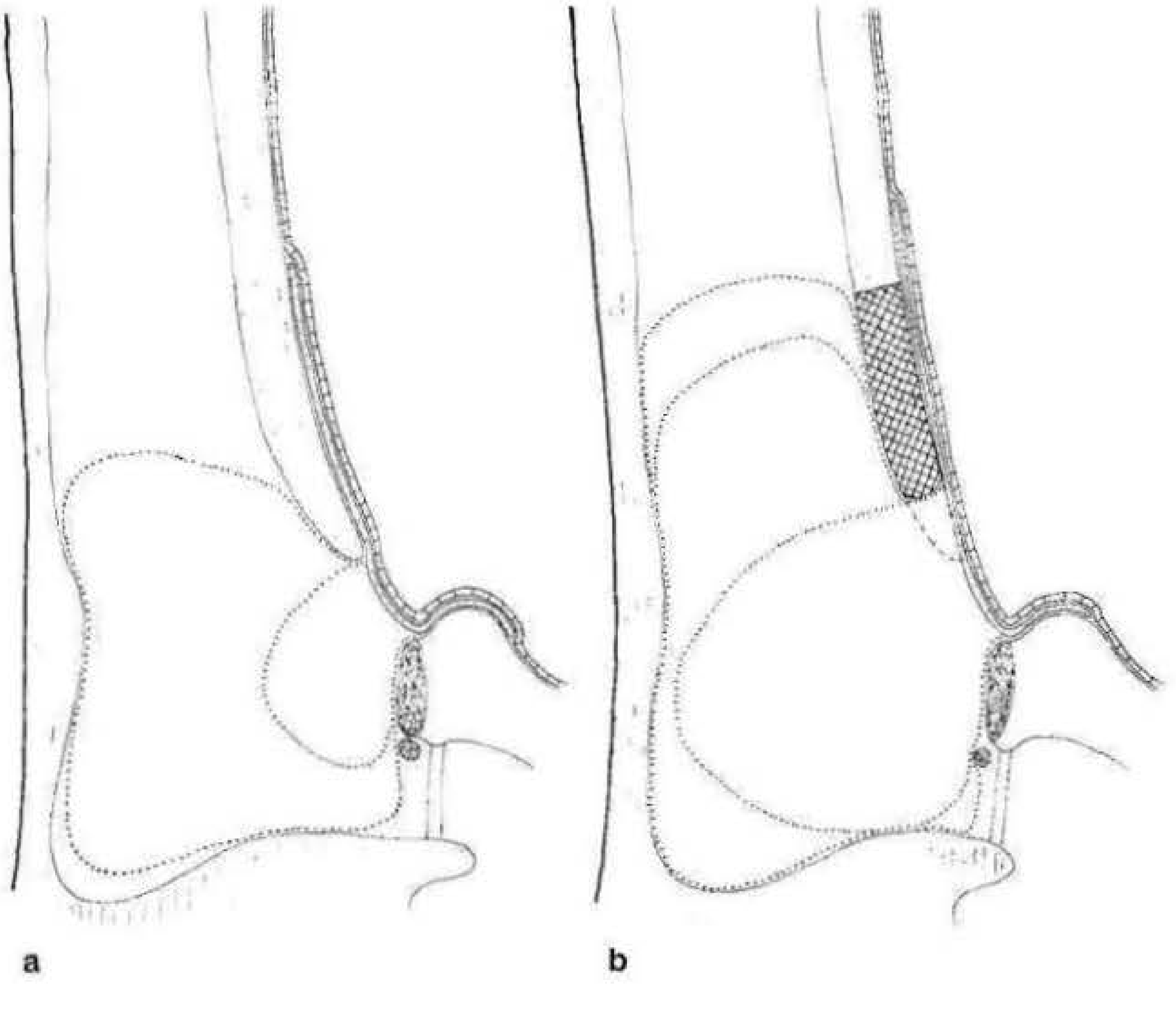


Fig. 378 Examples of retractions after classic intact canal wall mastoidectomy in a situation with an empty attic.
a The Scutum is normal. Retraction into an empty attic is not uncommon, even in a normal scutum.
b The scutum has partly been resorbed. Retraction will occur soon, and will progress, covering the mastoid aspect of the ear canal with keratinized epithelium and causing resorption of the scutum (dotted area)

Disappearance of the canal wall in classic intact canal wall mastoidectomy is termed *atrophy of the wall* by Weinberg and Sadé (1982), and is found in 18% of cases. It is considered a complication of the intact wall technique. Sanna et al. (1986) encountered it in only 5% of cases. If keratinized epithelium within a retraction pocket lies behind the canal wall, the wall is resorbed, and this resorption is in fact, in the present author's opinion, not a complication, since it gives the retraction pocket a large neck, which becomes safe and can be cleaned and inspected, avoiding a second-look operation.

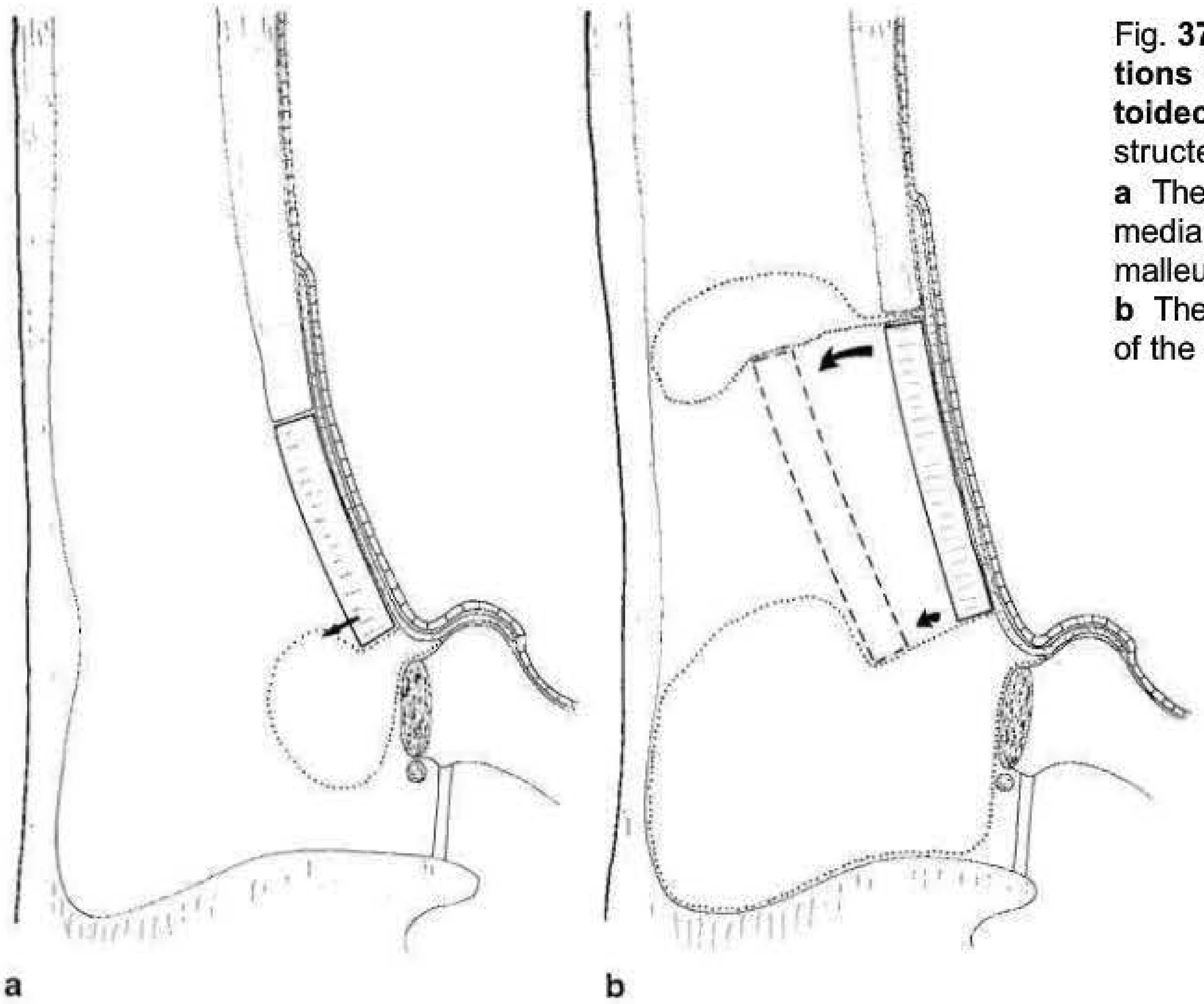


Fig. **379** **Examples of attic retractions in classic intact canal wall mastoidectomy.** The scutum defect is reconstructed with cartilage.

a The retraction may occur between the medial edge of the new scutum and the malleus neck.

b The retraction may occur at both ends of the cartilage, displacing it posteriorly.

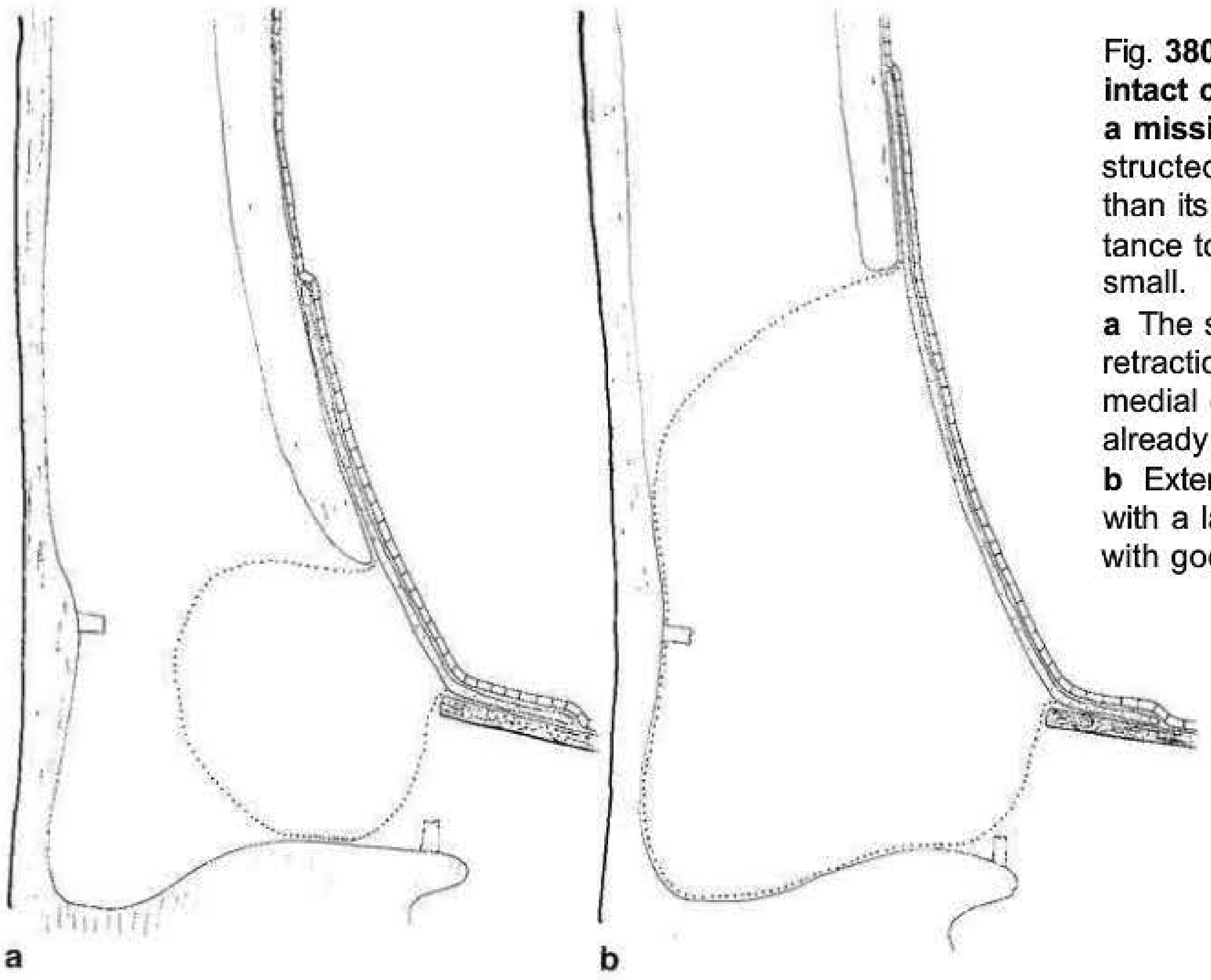


Fig. **380** **Examples of retractions in intact canal wall mastoidectomy with a missing malleus handle.** The recon structed drum is placed somewhat lower than its normal position, and the distance to the cochleariform process is small.

a The scutum is nearly normal, but retraction may occur between the medial end of the scutum and the already retracted pars tensa.

b Extensive resorption of the scutum, with a large retraction into the attic, but with good access to the retraction.

Cavity Obliteration Behind the Intact Canal Wall

The goal of intact canal wall mastoidectomy is the repneumatization of the cavity. Often, repneumatization does not occur, despite every effort to maintain a connection between the Eustachian tube and the mastoid, i. e., large anterior and posterior atticotympanotomies, a perfect scutumplasty, and extensive Silastic sheeting to the middle ear cleft from the orifice of the Eustachian tube to the antrum, as well as ventilation of the tympanic cavity and the mastoid cavity using ventilating tubes. Retraction often occurs, leading to retraction cholesteatoma and the need for reoperation.

When performing classic intact canal wall mastoidectomy, many surgeons recommend and routinely perform a second-stage operation, making further attempts to ventilate the mastoid cavity, remove new adhesions, repair the scutum, and fortify any retracted membrane, whether the tympanic membrane or of the attic wall. Some surgeons carry out obliteration of the cavity behind the intact or partly defective ear canal in order to prevent retraction and avoid reoperation.

The obliteration can be total, with no air at all within the attic, or partial, with some repneumatization of the attic but with obliteration behind the attic (Honda 1992). In total obliteration, it is very important that all cholesteatoma from the cavity and the attic should be removed. If there is any doubt about the cholesteatoma removal, an obliteration should not be performed, and a canal wall–down mastoidectomy technique should be applied. The obliteration can be performed with any accessible autogenous graft, e. g., muscle–subcutaneous tissue, fascia, tragal or conchal cartilage, bone chips, or bone paté.

Usually, obliteration is carried out in cases with large scutum defects and an empty attic. In such cases, a large tragal cartilage graft with attached perichondrium is placed behind the thinned bony ear canal (Fig. **381**). In order to separate the attic from the mesotympanum and prevent later retraction when the muscle becomes atrophic, the tragal cartilage has to be placed on the lateral semicircular canal and supported in the attic by other tissue, such as remaining pieces of tragal cartilage, conchal cartilage, or bone chips (Fig. **382**). Small slices of cartilage can be placed within the scutum defect at the bony margin (Fig. **381**). Finally, the cavity is filled with subcutis–muscle flaps that have a superior pedicle or an inferior pedicle, or both (Fig. **381**). A large anteriorly pedicled Palva flap (Fig. **383**) can also be very valuable. The present author starts any

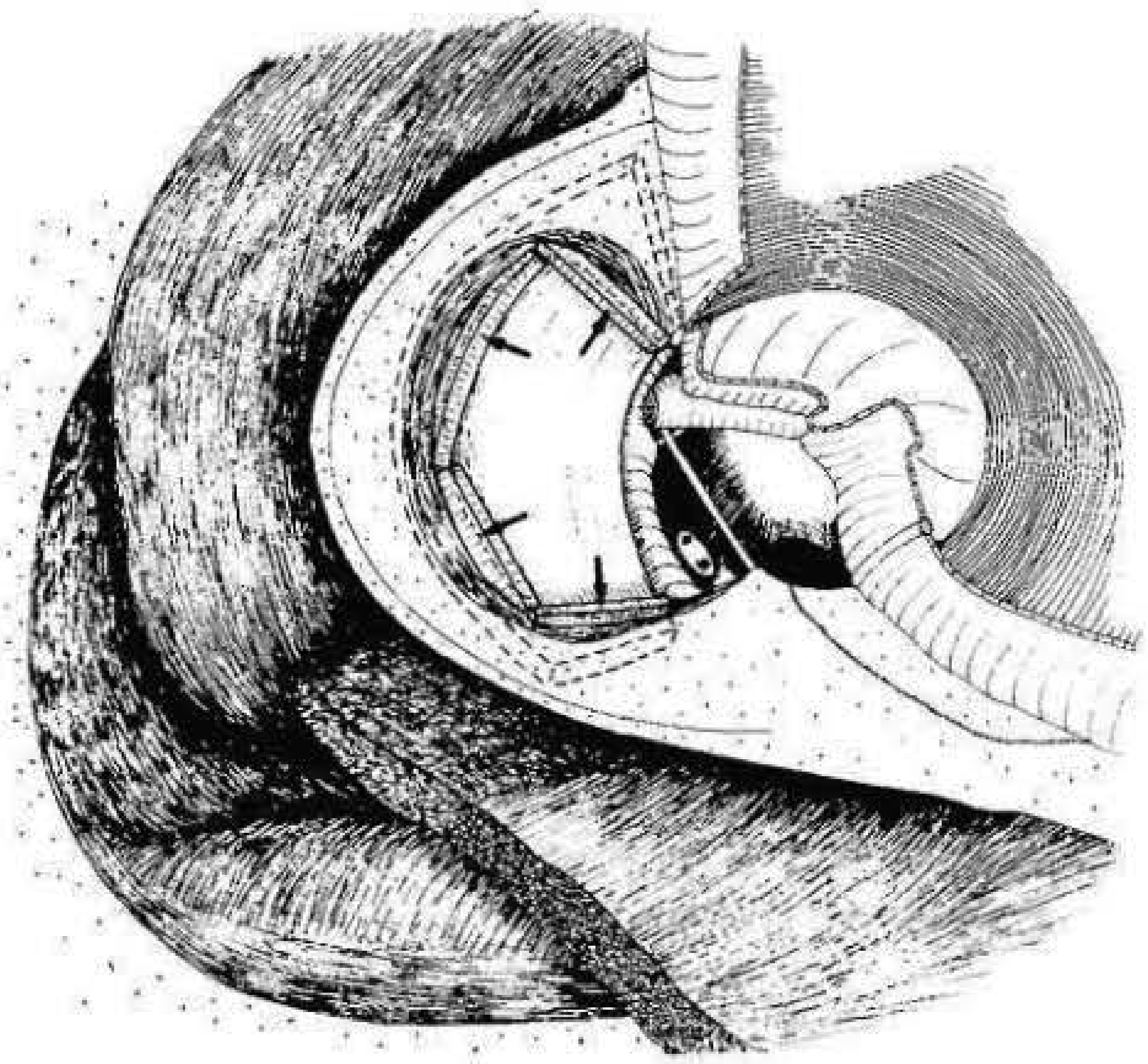


Fig. **381** **Obliteration of the mastoid cavity behind a preserved ear canal wall.** A large piece of tragal cartilage is placed behind the scutum defect on the medial wall of the attic. Additional small pieces of tragal cartilage are placed along the edges of the scutum defect to strengthen the scutumplasty (arrows). The attic is further obliterated with cartilage and bone, and the cavity is sealed with superiorly and inferiorly pedicled muscle grafts.

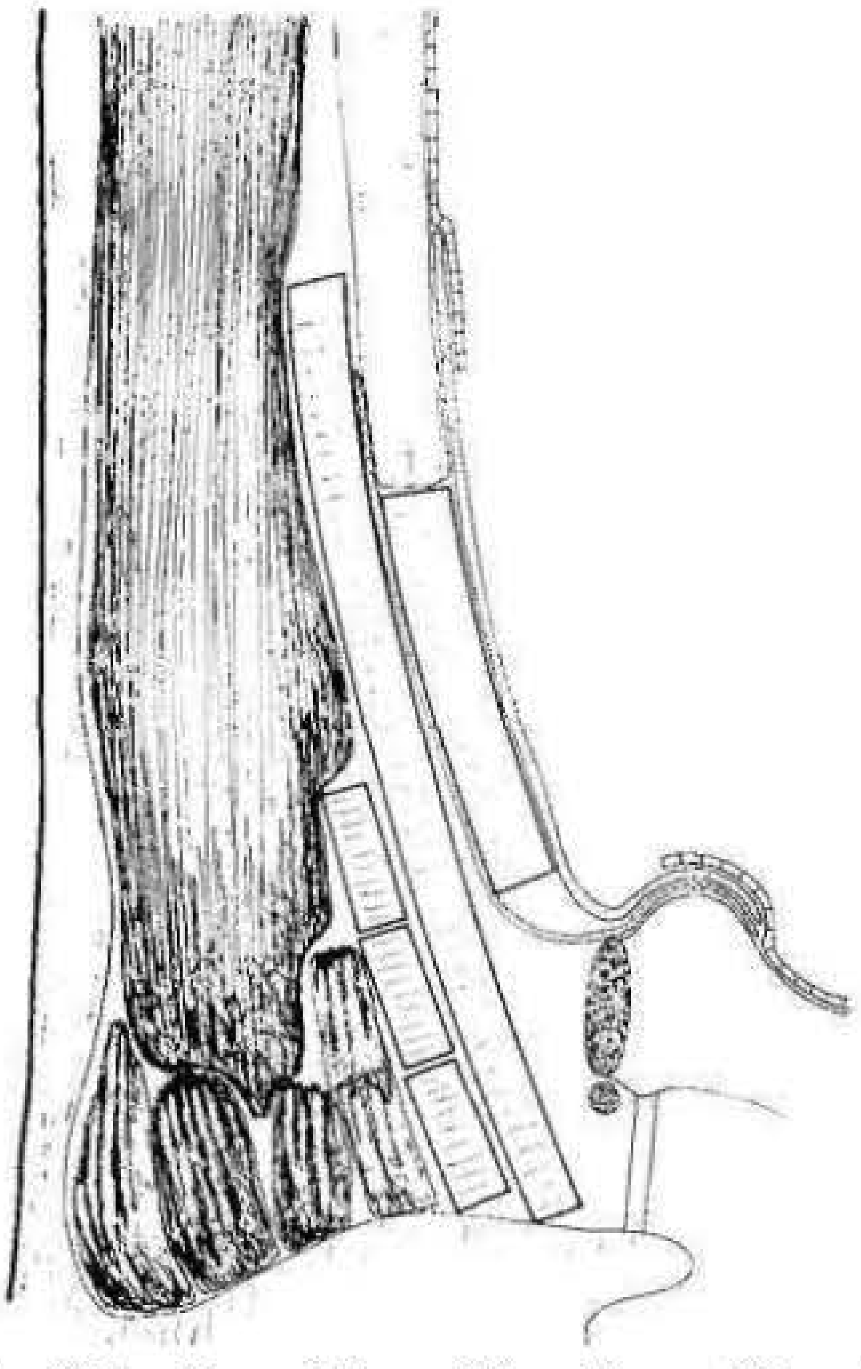


Fig. **382** **Side view of the obliteration of the attic in a case with a preserved ear canal wall.** A large piece of tragal cartilage is placed behind the ear canal wall and onto the medial wall of the attic. A cartilage–perichondrium compound graft is placed in the scutum defect, and the meatal wall is covered with fascia. Further obliteration of the attic with pieces of cartilage and cortical bone and a long muscle flap follows.

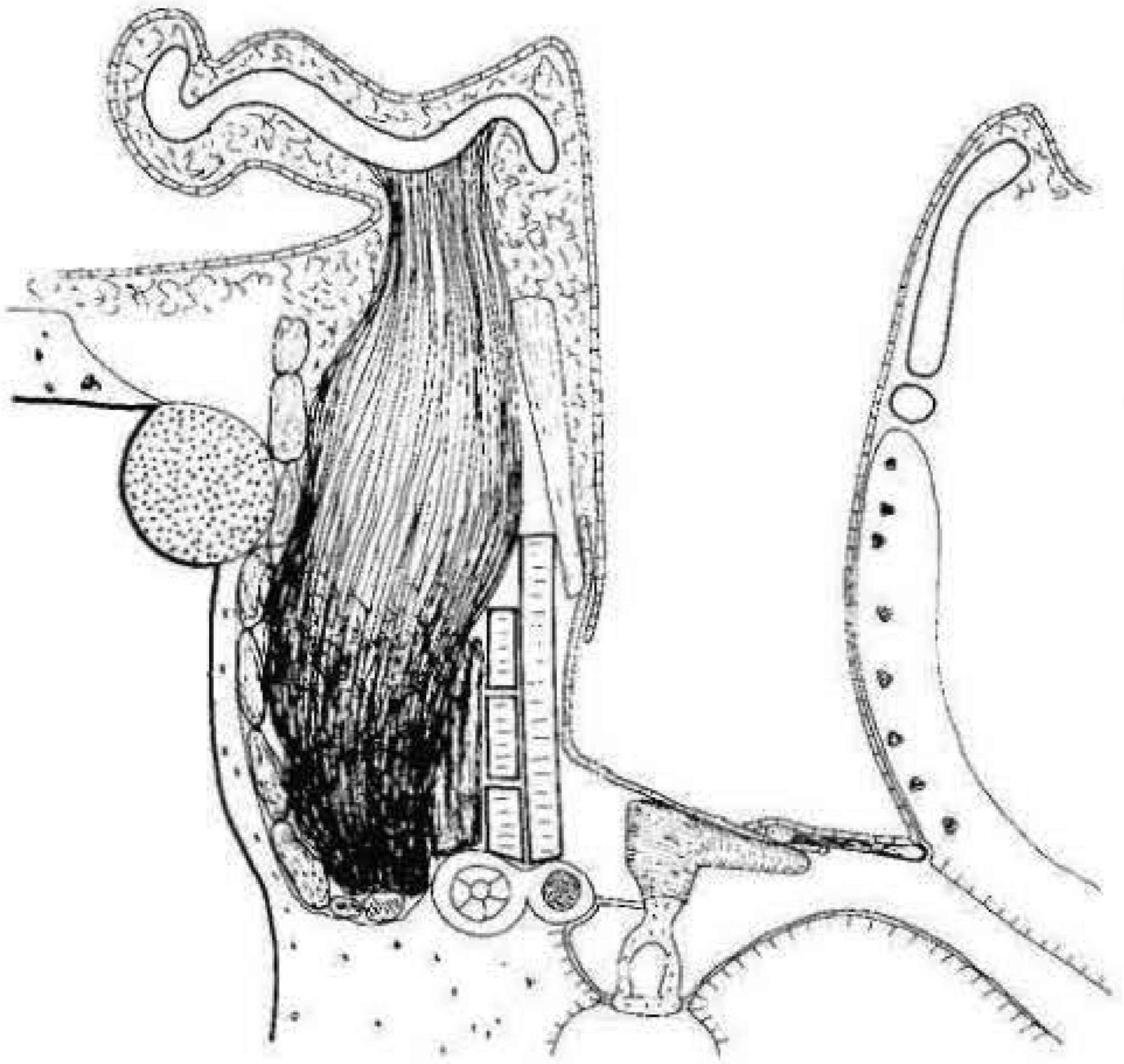


Fig. **383** **Examples of obliteration of the mastoid cavity with y Palva flap in an intact canal wall mastoidectomy** in a case with a scutum defect. The scutum defect is closed with a large piece of tragal cartilage, and further obliteration of the attic with cartilage and a Palva flap placed deep into the cavity follows. Posterior to the Palva flap are several bone chips

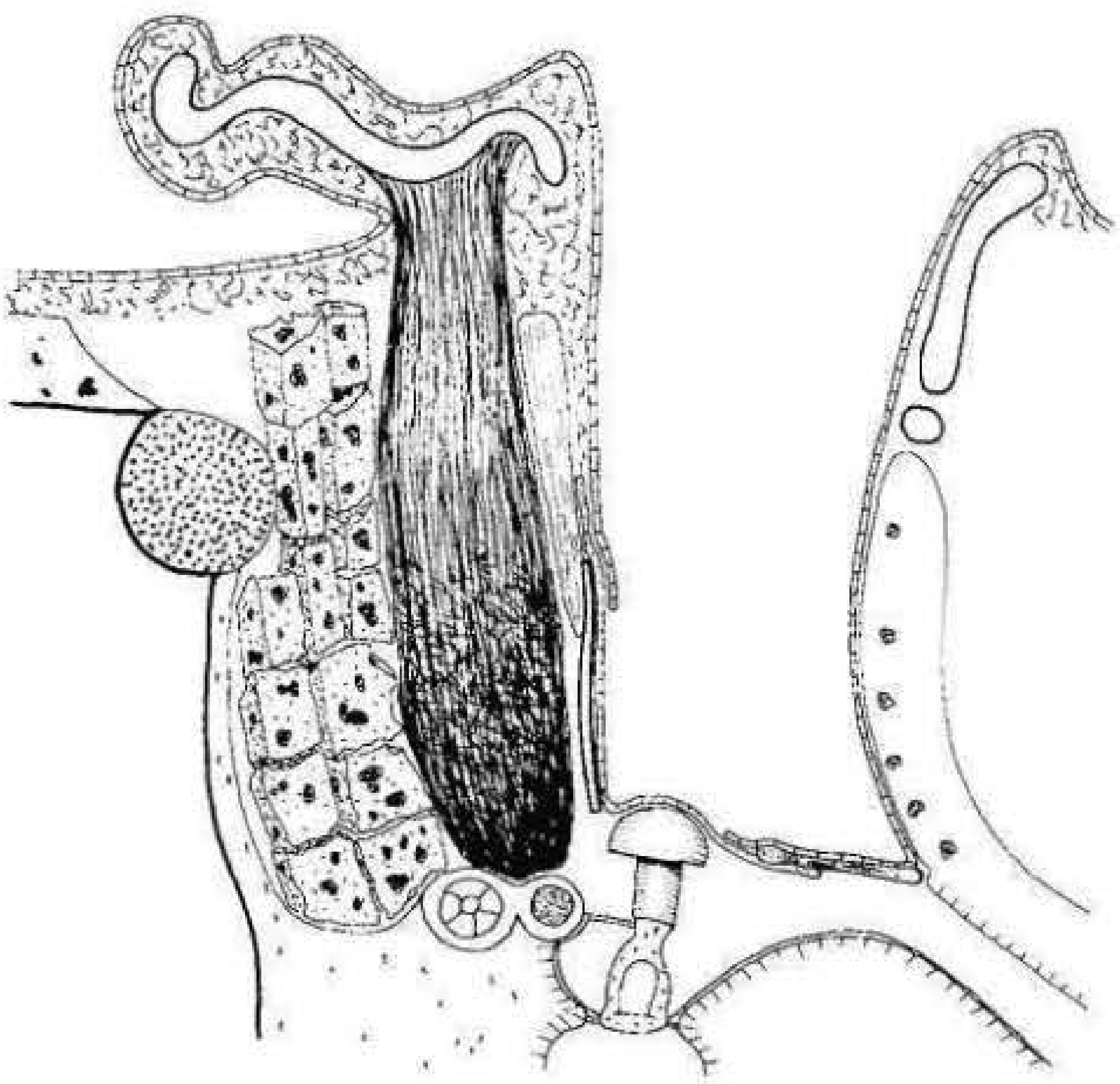


Fig. **384** **The Yanagihara obliteration technique** in the second-stage operation after an intact canal wall mastoidectomy. The scutumplasty is performed with a tragal cartilage placed on the edge of the bony ear cana wall and fascia. Behind the ear canal wall lies the Palva flap, and behind the Palva flap there are pieces of hydroxyapatite. A hydroxyapatite P-prosthesis is placed on the head of the stapes

intact canal wall mastoidectomy technique with a retroauricular flap incision (Volume 1, Figs. **135–147**), and always raises a large Palva flap to have it ready if obliteration is necessary. The obliteration techniques used in canal wall–down mastoidectomy are described separately in Chapters 18–22.

Yanagihara et al. (1972) and Gyo et al. (1972) carry out obliteration during the second stage without removal of the posterior bony ear canal. At the second stage, an average of 11 months after canal wall–up mastoidectomy, the first stage—the silicone rubber sheet—is removed, any remaining pathology is eradicated, and the ossicular chain is reconstructed. Defects in the ear canal are closed with auricular or tragal cartilage, when necessary. Mastoid obliteration at the second stage is carried out by Yanagihara as follows. First, ossiculoplasty using hydroxyapatite, followed by scutumplasty with tragal or conchal cartilage is performed. Obliteration is carried out using a long subcutis–muscle Palva flap, and behind the Palva flap blocks of hydroxyapatite are placed (Fig. **384**). One year after obliteration and further scutumplasty (for the second time), 50% of 50 ears that had undergone obliteration had some degree of retraction (Gyo et al. 1992). It is also interesting to note that, out of 124 ears with intact canal wall mastoidectomy and scutumplasty at the first stage, and insertion of a large, 0.5 mm-thick Silastic sheet, 38% developed retractions at an average of 11 months after the first-stage operation; the retraction was present even though the defect had been closed with cartilage, bone, or hydroxyapatite. Also of interest is the histological reaction present around the silicone sheet in 109 cases at the second stage. In 19%, there was no surrounding tissue around the Silastic. In 44%, the Silastic was surrounded by thin tissue, and in 37% by thick tissue. Retraction pockets appeared in a high percentage of cases in which the Silastic was surrounded only by thin tissue. In cases with thick tissue around the attic, the incidence of retraction was low, simply because there was no space present, although these cases showed the most severe histological reaction, and when the Silastic and the fibrous tissue is removed there would probably be no repneumatization of the ears. It is also interesting to note that, out of 124 ears undergoing a planned two-stage tympanoplasty after a classic canal wall–up procedure, performed over a ten-year period (1981–1990), a high percentage of ears developed retraction pockets despite two scutumplasties, one at the primary operation and one at the second-stage operation. In addition, a high percentage of patients underwent obliteration behind the preserved ear canal, and among these ears, a high percentage developed retraction pockets after the second stage.

The Honda Partial Obliteration Method

This method is characterized by scutumplasty, repneumatization of the attic, and separation of the attic from the antrum by obliteration of the antrum and the remaining cavity using bone paté, and with muscle grafts if necessary (Honda 1992). First, scutumplasty is performed using the Honda method, with fascia and trimmed tragal or conchal cartilage (Figs. **355, 356**) covering the scutum and glued to the bone, Secondly, one or two pieces of cartilage are placed to separate the attic from the antrum (Fig. **385**). The cartilage is covered, and the resulting cavity is obliterated with bone paté and fibrin glue (Fig. **386**).

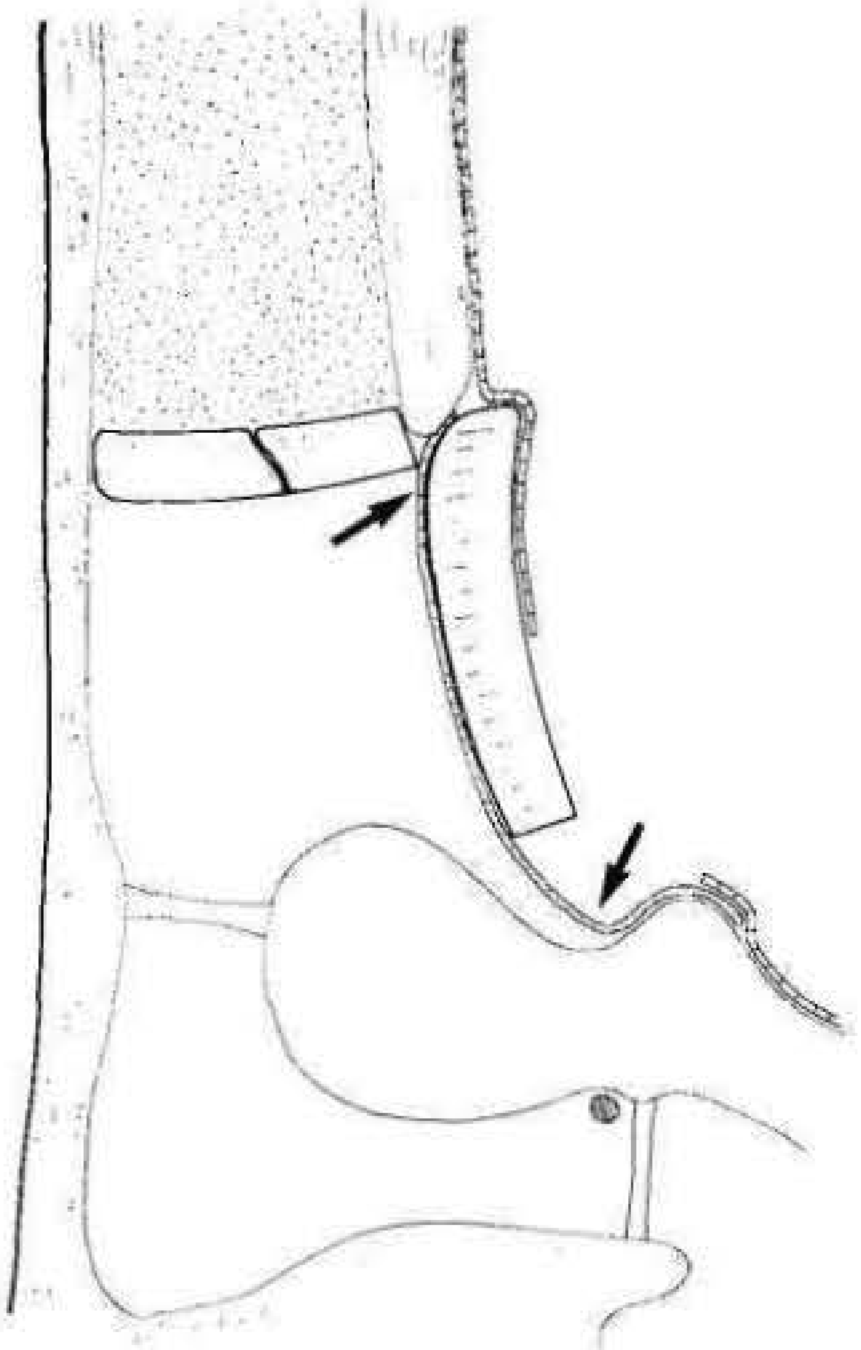


Fig. **385** **The Honda partial obliteration technique.** The scutumplasty is performed with conchal cartilage and fascia placed on the mastoidal aspect of the scutum defect (arrows). The lateral part of the attic is covered with conchal cartilage, separating the attic from the remaining cavity. Bone paté is placed lateral to the cartilage, obliterating the cavity

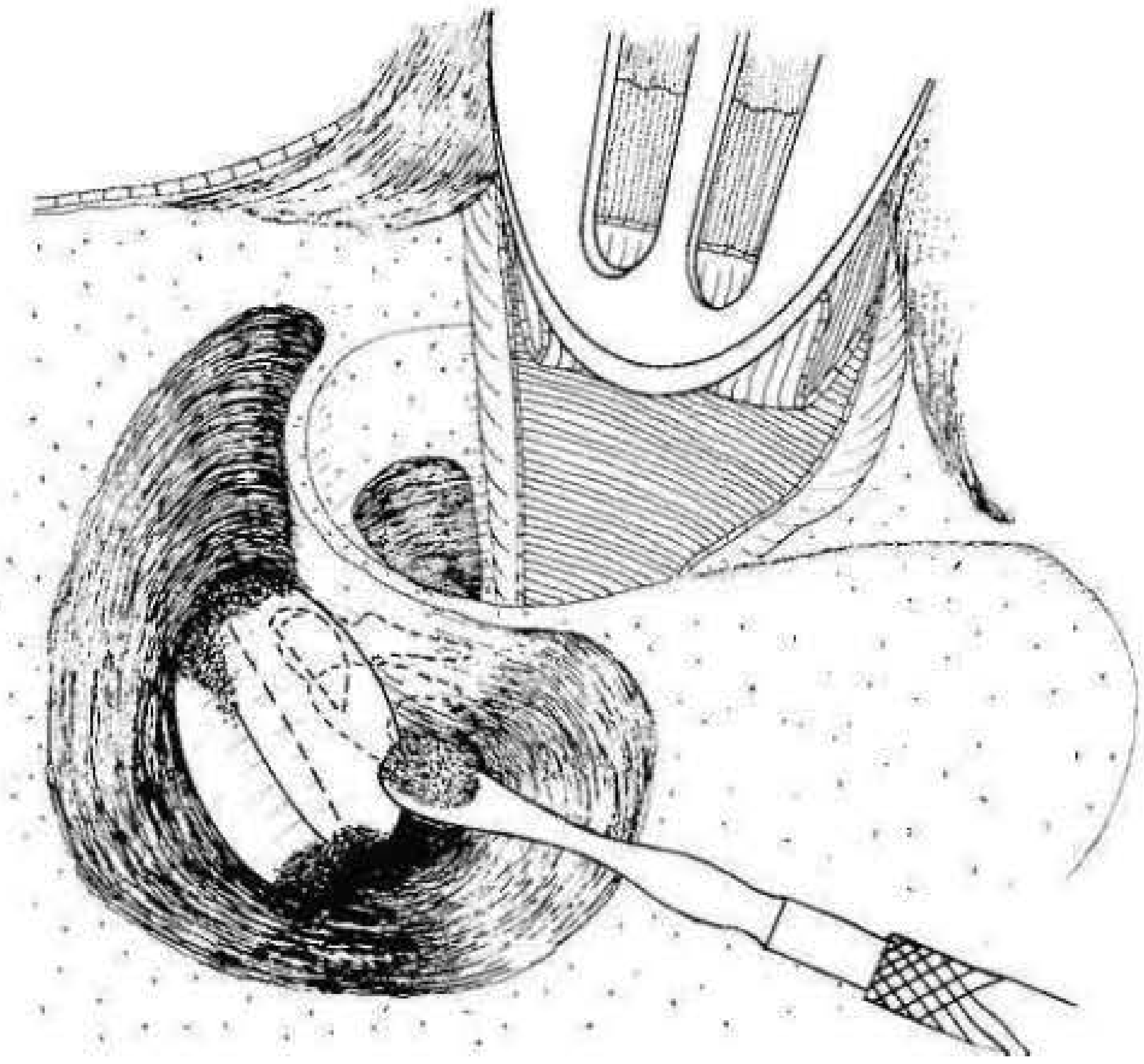


Fig. **386** **The Honda partial obliteration technique.** Two pieces of cartilage are covering the lateral part of the attic and separating the antrum from the attic. The scutumplasty is indicated by a dashed line. The cavity is obliterated with bone paté

7 Modified Combined Approach Tympanoplasty

The classic combined-approach tympanoplasty, or the classic intact canal wall mastoidectomy, consists of a large mastoidectomy with an intact but thin bony ear canal wall and a posterior atticotympanotomy. Removal of cholesteatoma from the anterior attic through the mastoidectomy and from the tympanic sinus through the posterior atticotympanotomy is complicated, especially under narrow anatomic conditions, and the significant frequency of residual cholesteatoma found in these two regions is therefore not surprising (Sheehy 1970 b, Glasscock and Miller 1976, Abramson et al. 1977, Austin 1977, Smyth 1976, Cody and Taylor 1977, Sadé 1977, Sheehy et al. 1977, Wright 1977, Schwaber 1979).

Since 1970, the present author has used his own modification of combined-approach tympanoplasty or modified intact canal wall mastoidectomy (Tos 1978 a, Tos 1982 a). This modification is based on different surgical principles to the classic intact canal wall mastoidectomy and on a novel philosophy, i. e., creating conditions in the attic such that retraction does not necessarily lead to recurrent cholesteatoma requiring reoperation, but is more likely to result in a small but stable cavity with a wide neck. In addition, any residual cholesteatoma can be observed through the atticotomy opening, obviating the need for a second-look or two-stage operation.

Definition

The following features characterize this modification: 1) retroauricular approach; 2) transmeatal posterior tympanotomy with drilling of the superoposterior bony annulus ("otosclerosis drilling"); 3) removal of pathology from the tympanic cavity, especially the tympanic sinus and the stapes region; 4) transmeatal atticotomy with preservation of the bony bridge and removal of cholesteatoma from the attic; 5) transcortical intact canal wall mastoidectomy with maximal thinning of the posterior and superior bony ear canal wall and removal of pathology from the antrum and mastoid process (Figs. **32**–**36**).

Surgical Technique

Approach

Initially through an ear speculum, a circumferential incision is performed starting anteriorly at the 3-o'clock position, continuing towards the 12-o'clock position, and then around to the 5-o'clock position. Then, using the sickle knife, a radial incision is made at the 5-o'clock and another at the 12-o'clock positions, starting at Shrapnell's membrane (Fig. **387**). The purpose of these incisions is to avoid tearing the ear canal skin during elevation.

A retroauricular incision, 1 cm behind the postauricular fold, is performed, going through the skin, subcutaneous tissue, and periosteum directly to the bone. The subcutaneous flap is elevated toward the suprameatal spine and the entrance of the bony meatus. The posterior part is elevated, exposing the cortical bone of the mastoid process.

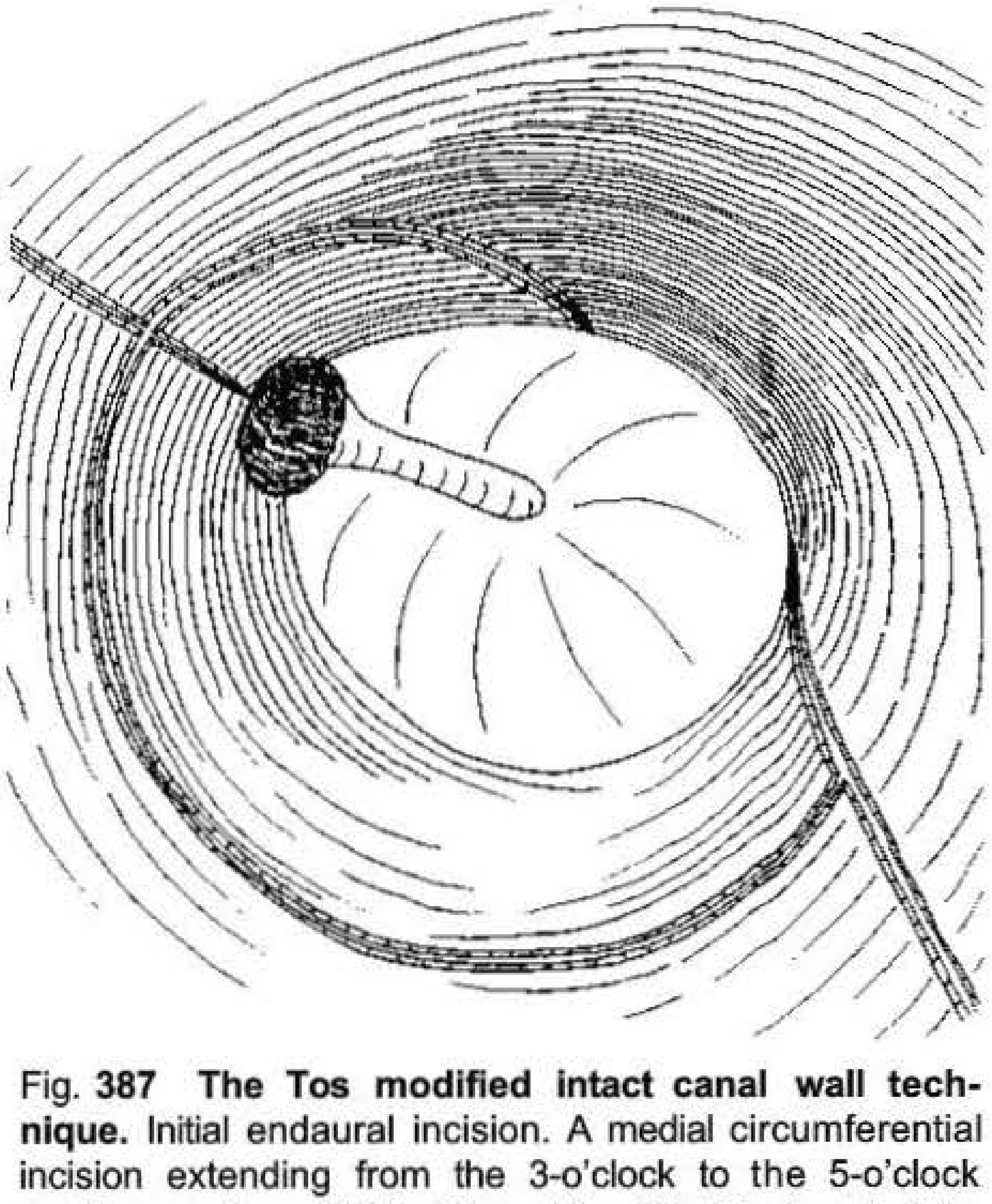


Fig. 387 **The Tos modified intact canal wall technique.** Initial endaural incision. A medial circumferential incision extending from the 3-o'clock to the 5-o'clock positions and a radial incision at the 12-o'clockand at the 5-o'clock positions

The skin–subcutis is held in place with a selfretaining retractor, and the elevation of skin from the posterior half of the car canal proceeds as far as the previously performed circumferential incision, approximately 6 mm lateral to the annulus. The advantage of the previously performed circumferential and radial incision is now evident, and the laterally-based posterior ear canal skin flap can easily be elevated, pushed anteriorly, and held in place using a House–Sheehy, protecting, selfretaining retractor (Fig. **388**). The meatal skin is carefully elevated from the superior bony wall, including the tympanosquamous suture, which is entirely exposed. The ear canal skin, anteriorly as far as the 2-o'clock position and inferiorly as far as the 5-o'clock position, is also elevated (Fig. **389**). The extent of the elevation of the ear canal skin depends on the cholesteatoma type. In attic cholesteatoma with pathology particularly in the anterior attic, the elevation of the skin must extend far anteriorly, but to a lesser extent inferiorly, in the ear canal. In sinus cholesteatoma or tensa retraction cholesteatoma the elevation of the skin has to be extensive inferiorly in the ear canal.

The posterior tympanomeatal flap along with the fibrous annulus is elevated, and a large posterior tympanotomy is performed, exposing the posterior part of the tympanic cavity as well as the ossicular chain (Fig. **389**).

Removal of Attic Cholesteatoma

After elevating the posterior malleolar ligament, and after following the chorda tympani toward the neck of the malleus, a small curved rougine is placed between the neck of the malleus and the neck of the cholesteatoma membrane as a search is made for a dissection plane in order to create a small malleus flap (Fig. **390**). The cholesteatoma membrane from the neck of the malleus is now elevated, creating the small malleus flap (Fig. **391**), and the ear canal skin anterior to Shrapnell's membrane is also elevated. The malleus flap is thus created from the elevated retracted membrane from the malleus neck. It is attached to the short process of the malleus.

Otosclerosis Drilling

With a small diamond burr, so-called otosclerosis drilling is then performed, i. e., removal of the posterosuperior bony annulus, exposing the entire tympanic sinus and the stapes (Fig. **391**). Any pathology, especially within the sinus typmpani, is carefully dissected, particularly the original cholesteatoma coming from the attic. The purpose of the otosclerosis

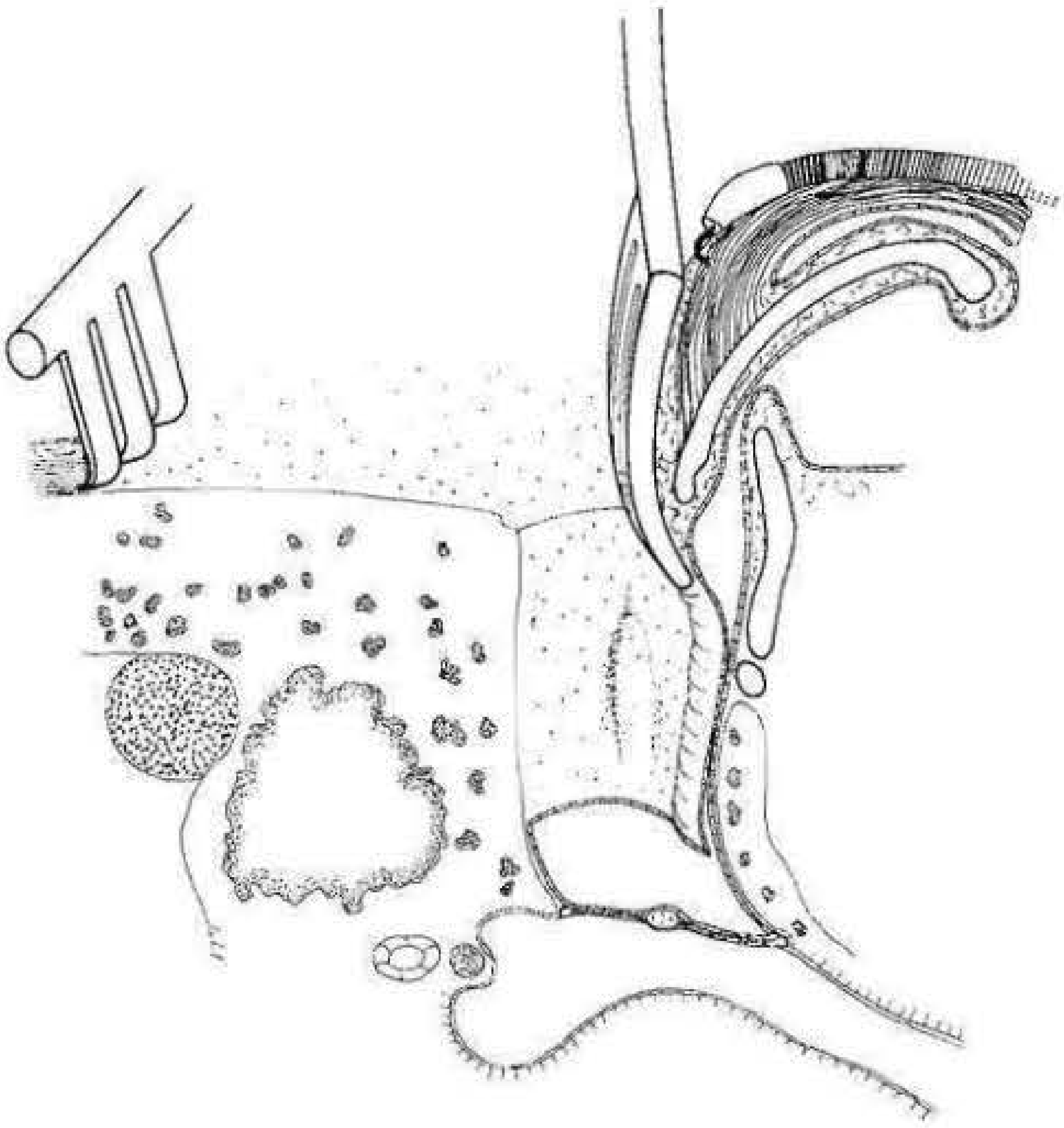


Fig. **388** Side view from same perspective of the retroauricular approach, with the posterior ear canal skin flap elevated, pushed anteriorly, and held in place with an House–Sheehy protective selfretaining retractor. At the superior wall, the tympanosquamous suture is indicated

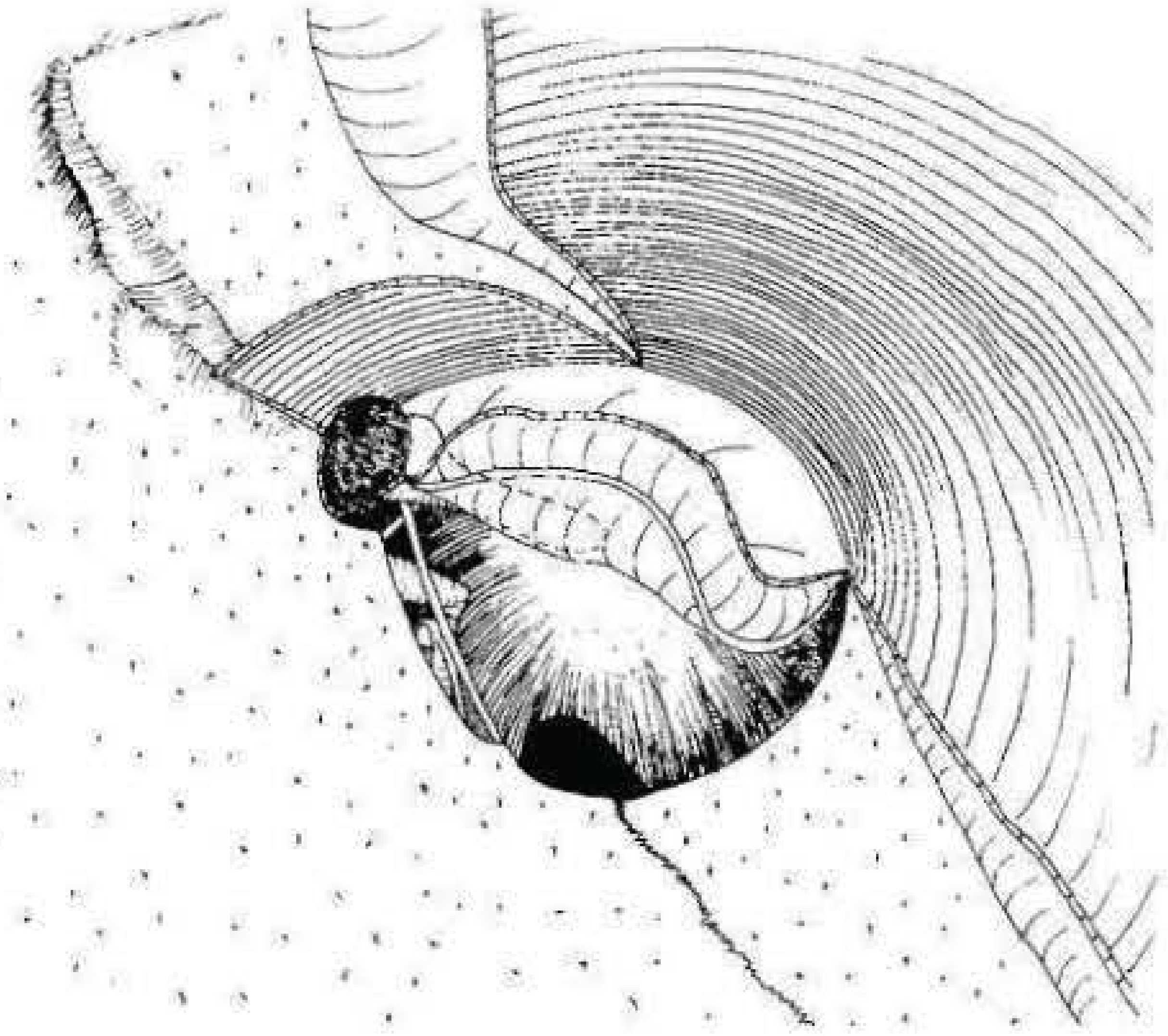


Fig. **389** View through the retroauricular approach into the tympanic cavity in a case of attic cholesteatoma with perforation, or retraction, in the Shrapnell's membrane region, without major bone resorption of the frame. The canal skin is elevated anteriorly and inferiorly. The posterior canal skin flap is elevated and held in place on the anterior aspect of the ear canal, as shown in Fig. 388. A posterior tympanotomy is performed, and the tympanic cavity is inspected

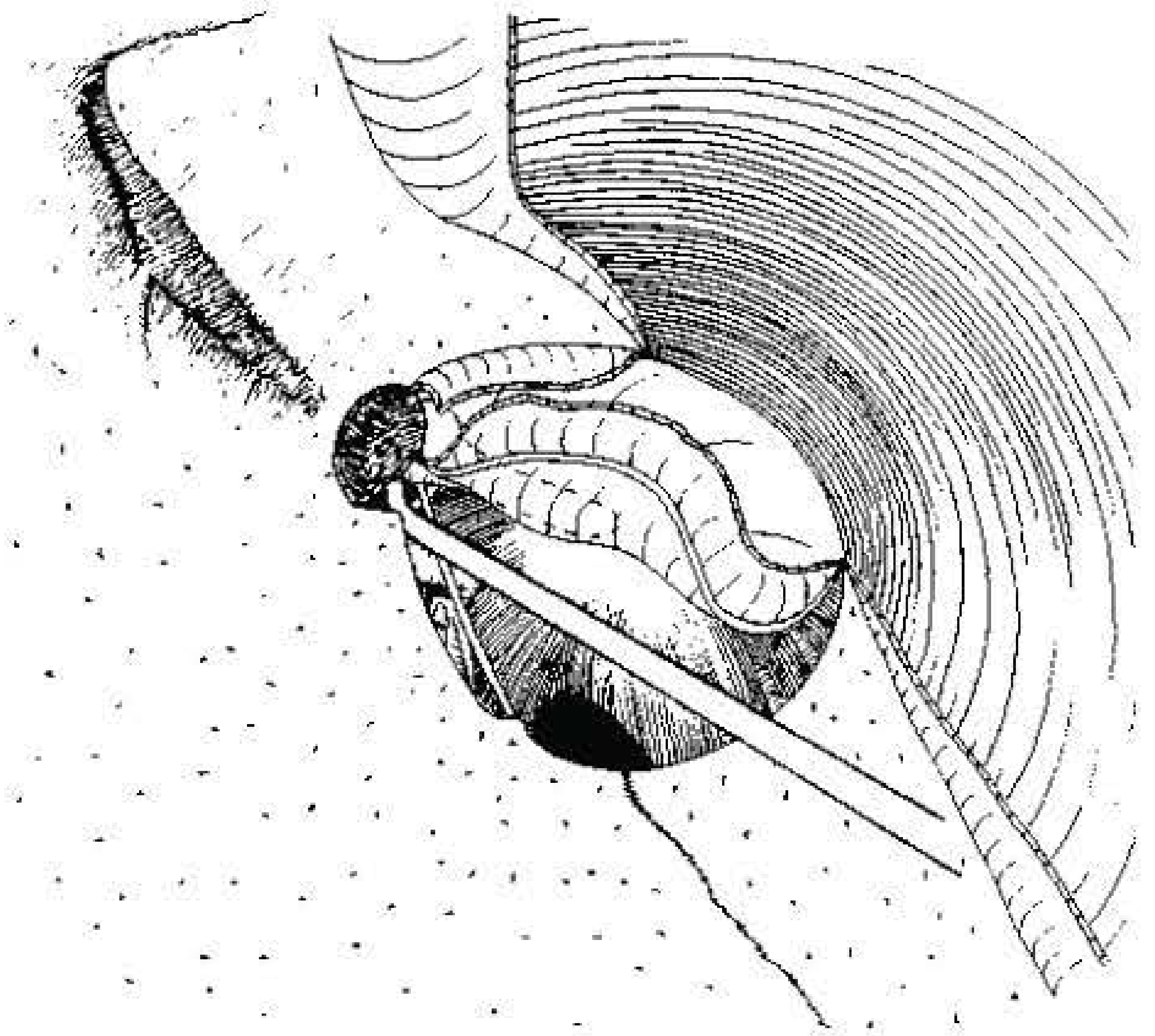


Fig. **390** With a curved elevator, a dissection plane is established between the neck of the malleus and the retraction of Shrapnell's membrane, elevating the retraction in order to create a small malleus flap

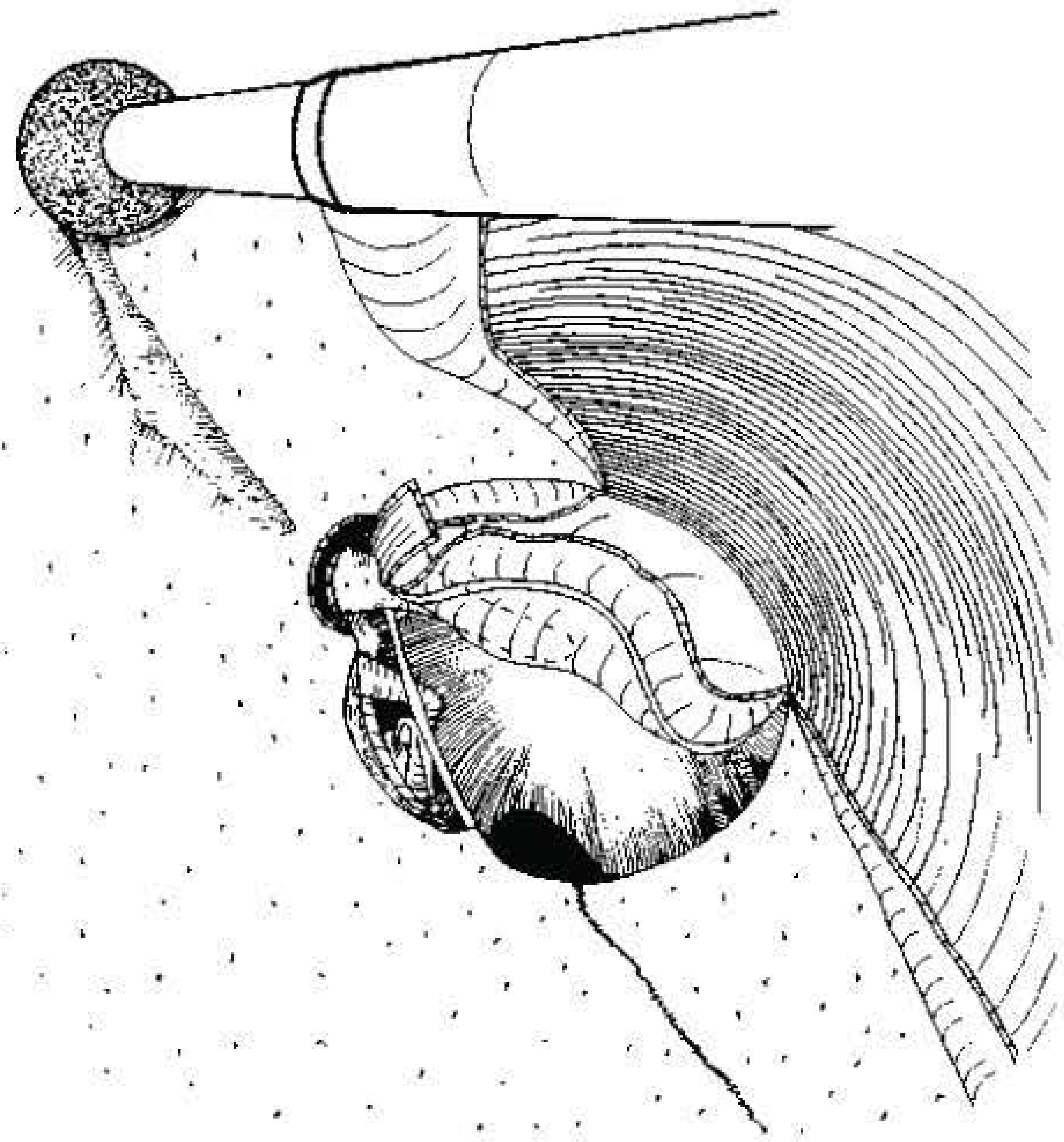


Fig. **391** **Otosclerosis drilling.** The malleus flap is elevated, with the base at the short process of the malleus. The malleus neck is cleaned of cholesteatoma, but the neck of the cholesteatoma sac extending into the attic is still in place and visible. Otosclerosis drilling of the posterosuperior bony annulus is performed, and the sinus tympani, the stapes region, and all the posterior tympanum is carefully inspected, with any cholesteatoma being safely removed from these regions. The drilling along the tympanosquamous suture is indicated

drilling is, at an early stage in the operation, to certify the condition of the ossicular chain and to dissect the cholesteatoma from the sinus tympani under optimal conditions. The author is convinced that surgery around the stapes and in the tympanic sinuses is more easily and safely performed with the same technique as that for stapedectomy surgery. In majority of cases using this method, pathology from the posterior tympanum and tympanic sinuses can be safely removed, and a posterior atticotympanotomy is unnecessary in this approach. Therefore, one of the essential differences in this modification is that a posterior atticotympanotomy is not performed (Fig. **391**).

Transmeatal Atticotomy

Before performing a transmeatal atticotympanotomy, the irregularities of the superior bony wall, including the tympanosquamous suture, are drilled away using a large diamond burr. It is important to carefully dissect the skin, and sometimes the fibrous tissue between the skin and the tympanosquamous suture has to be cut with a pair of scissors or a knife (Fig. **391**). By continuous drilling of the ear canal along the tympanosquamous suture, a small plateau is created at the level of the lateral attic wall, which facilitates the atticotomy (Fig. **392**). With further drilling, the plateau at the lateral attic wall is enlarged, and the size of bridge to be preserved is carefully assessed. The ear canal is further drilled toward the anterior attic, enlarging and thinning the plateau, which is to be perforated (Fig. **393**). Using a small diamond burr placed in the middle of the plateau, a hole is drilled through the bone, thus exposing the attic cholesteatoma as a whitish membrane (Fig. **394**) — whereas, if there is no cholesteatoma, the bluish mucosa is clearly visible. The thinned bone of the lateral attic wall is gradually drilled away, exposing more and more of the cholesteatoma membrane (Fig. **395**). The removal of the lateral attic wall is continued posteriorly (Fig. **396**) and the entire attic is thus exposed. The bony bridge is thinned, but remains intact.

Early in the operation, the neck of the malleus has been cleaned, and the cholesteatoma membrane covering the neck of the malleus elevated (Figs. **390, 391**). The cholesteatoma membrane is carefully elevated from the bony edges of the Shrapnell's membrane region. The cholesteatoma within the tympanic cavity is removed, and the membrane is pushed under the bridge along the long process of the incus and into the attic.

Before debulking the cholesteatoma, the membrane is incised with a sickle knife (Fig. **397**) and the

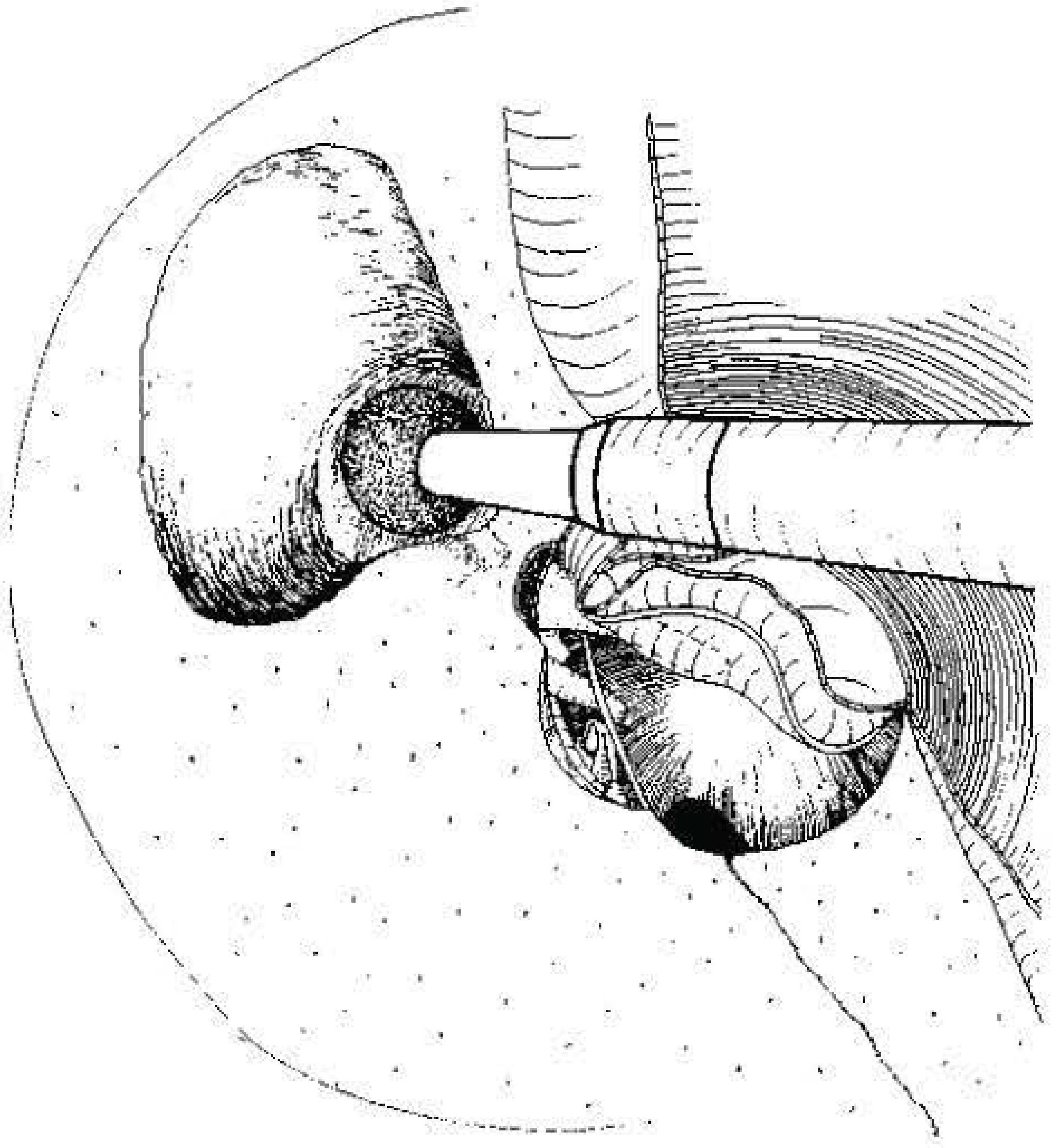


Fig. **392** **Atticotomy.** Drilling of the bone along the tympanosquamous suture is continued medially with a diamond drill, creating a plateau at the lateral attic wall region

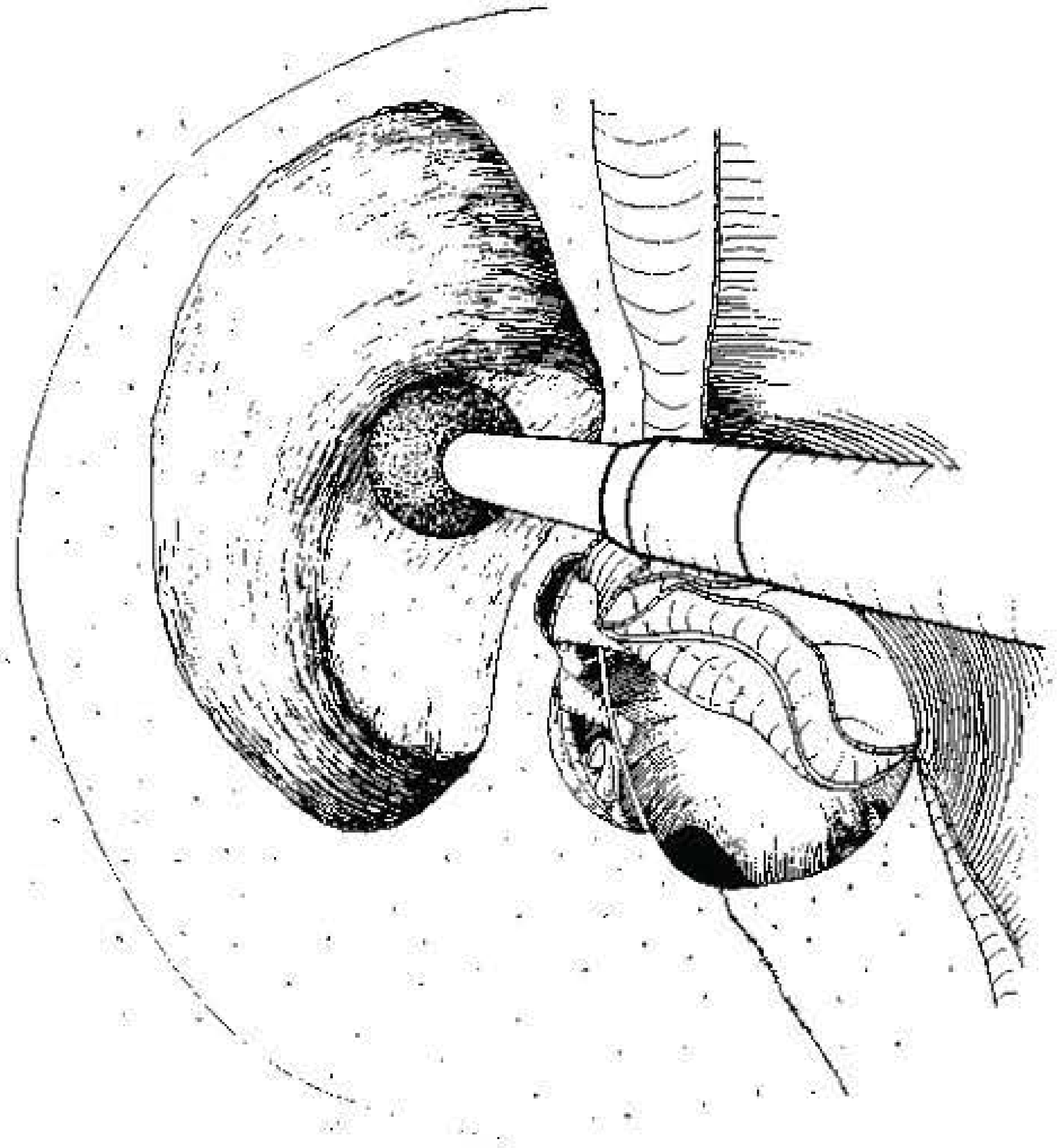


Fig. **393** The bony plateau lateral to the attic is enlarged, and the bony plate is thinned, with the bridge being kept intact

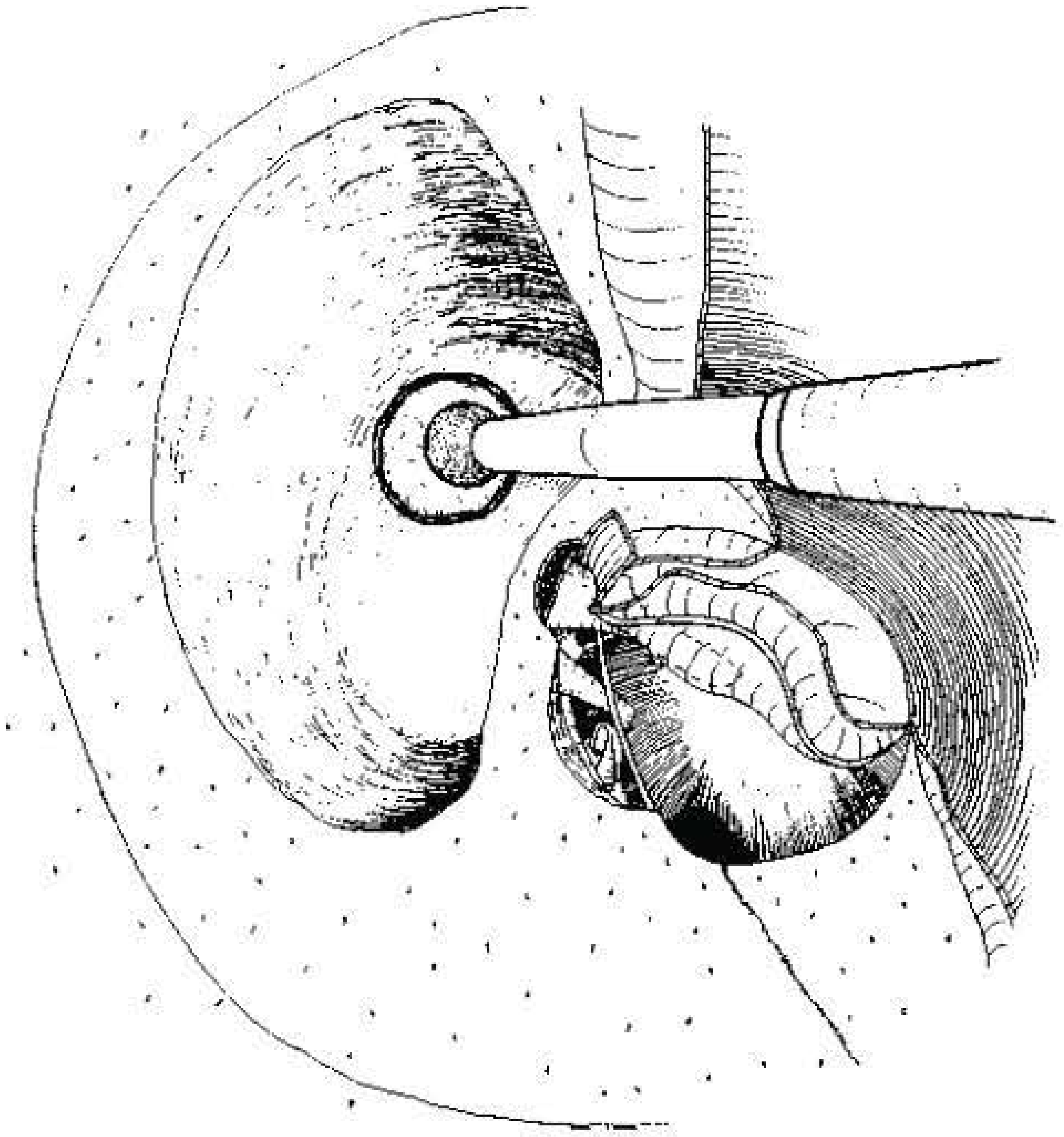


Fig. **394** The lateral attic wall is drilled away, and the attic is entered, exposing the cholesteatoma

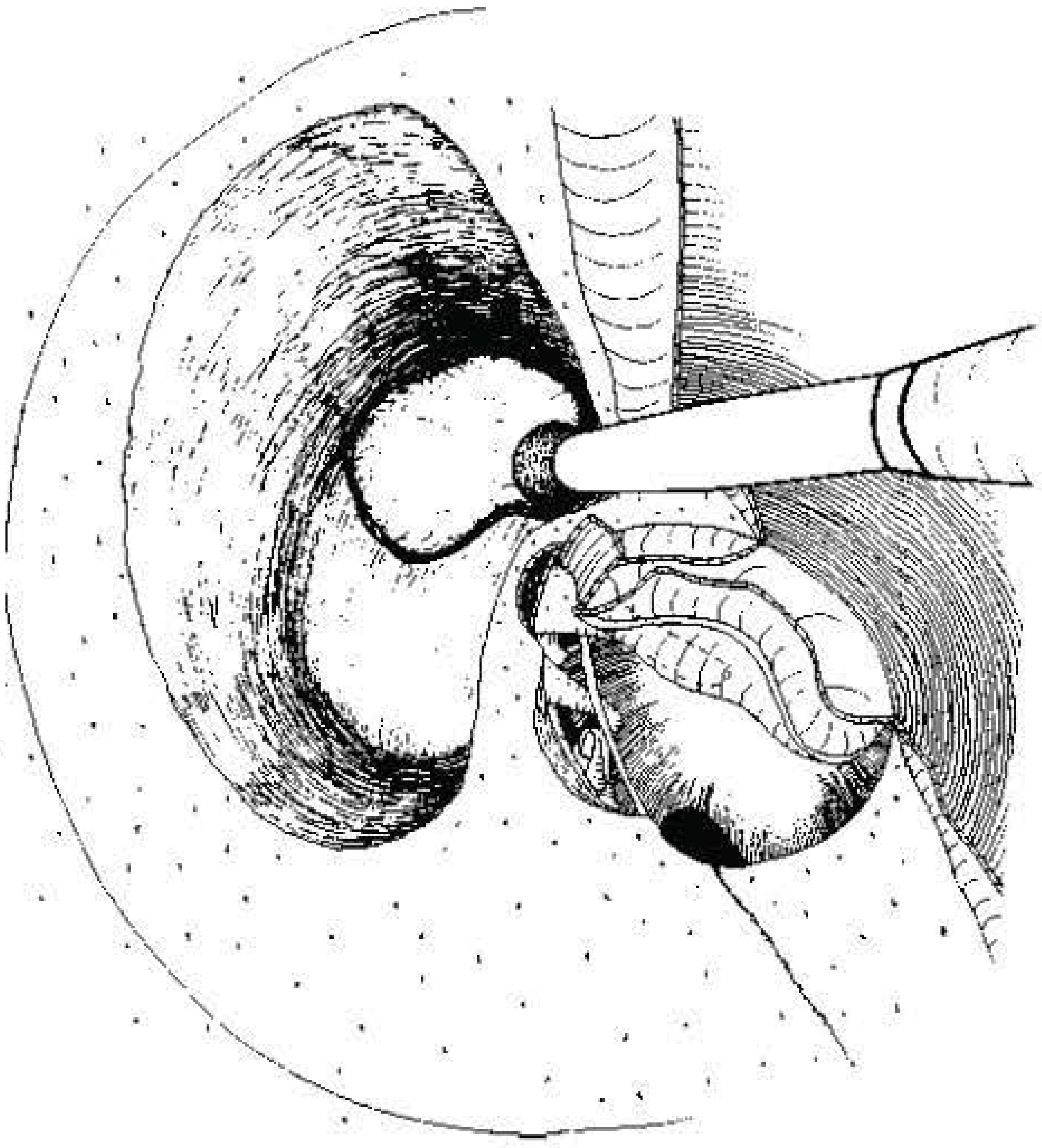


Fig. **395** Further removal of the lateral attic wall with a diamond burr

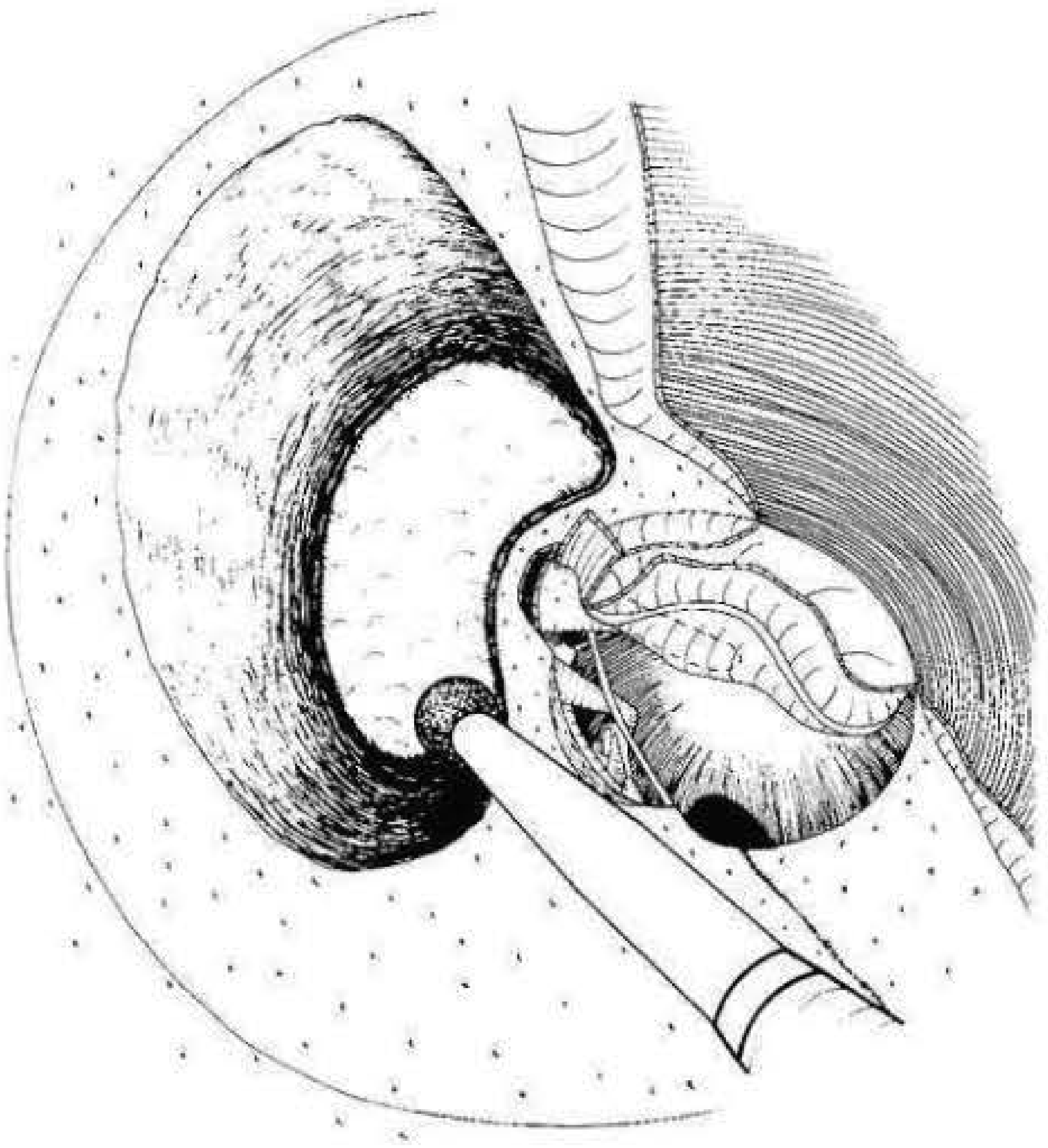


Fig. **396** The atticotomy has been completed. The bony bridge is preserved, and all the cholesteatoma in the attic has been exposed

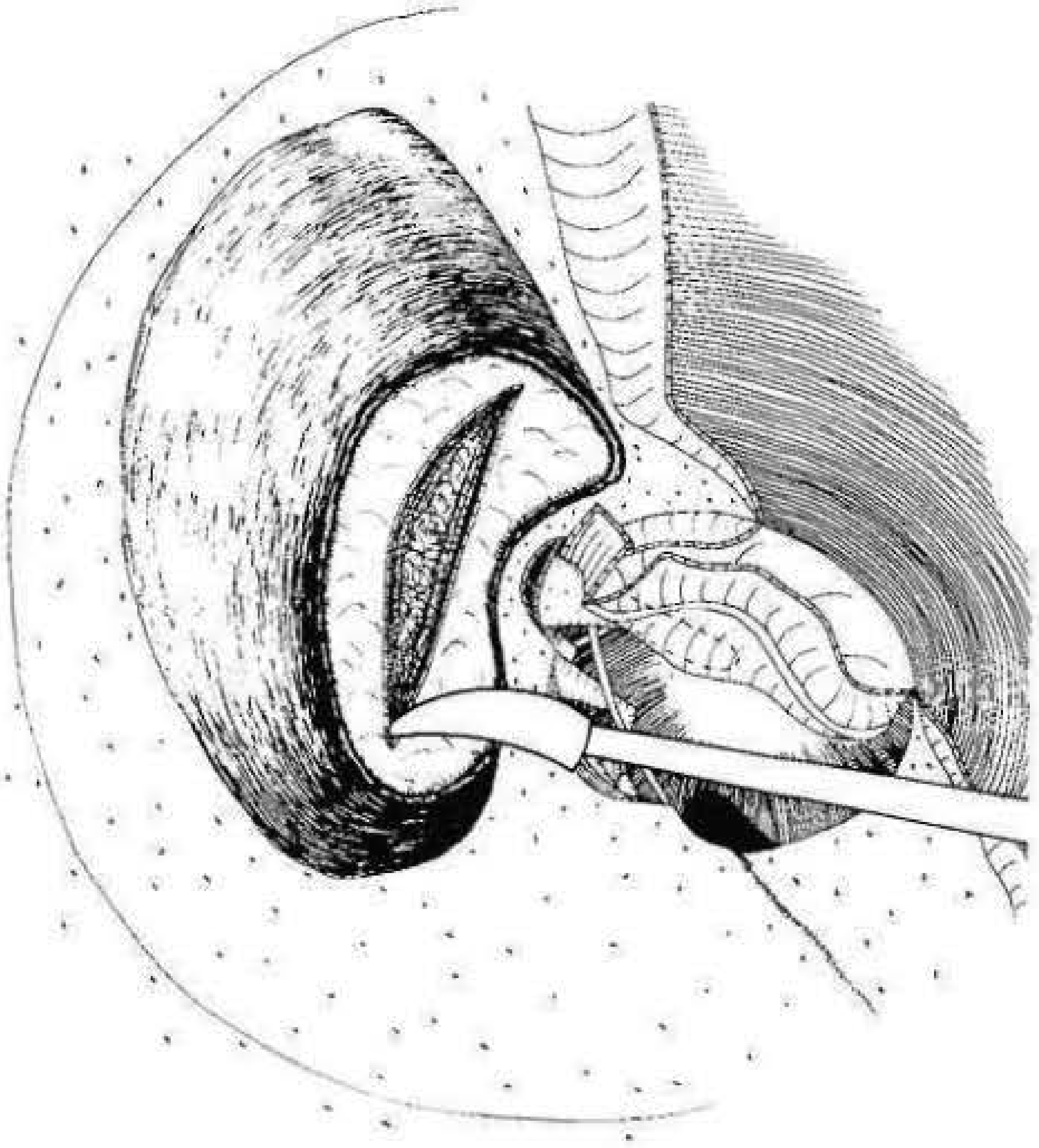


Fig. **397** **Dissection of the attic cholesteatoma.** The cholesteatoma sac is incised and will be debulked

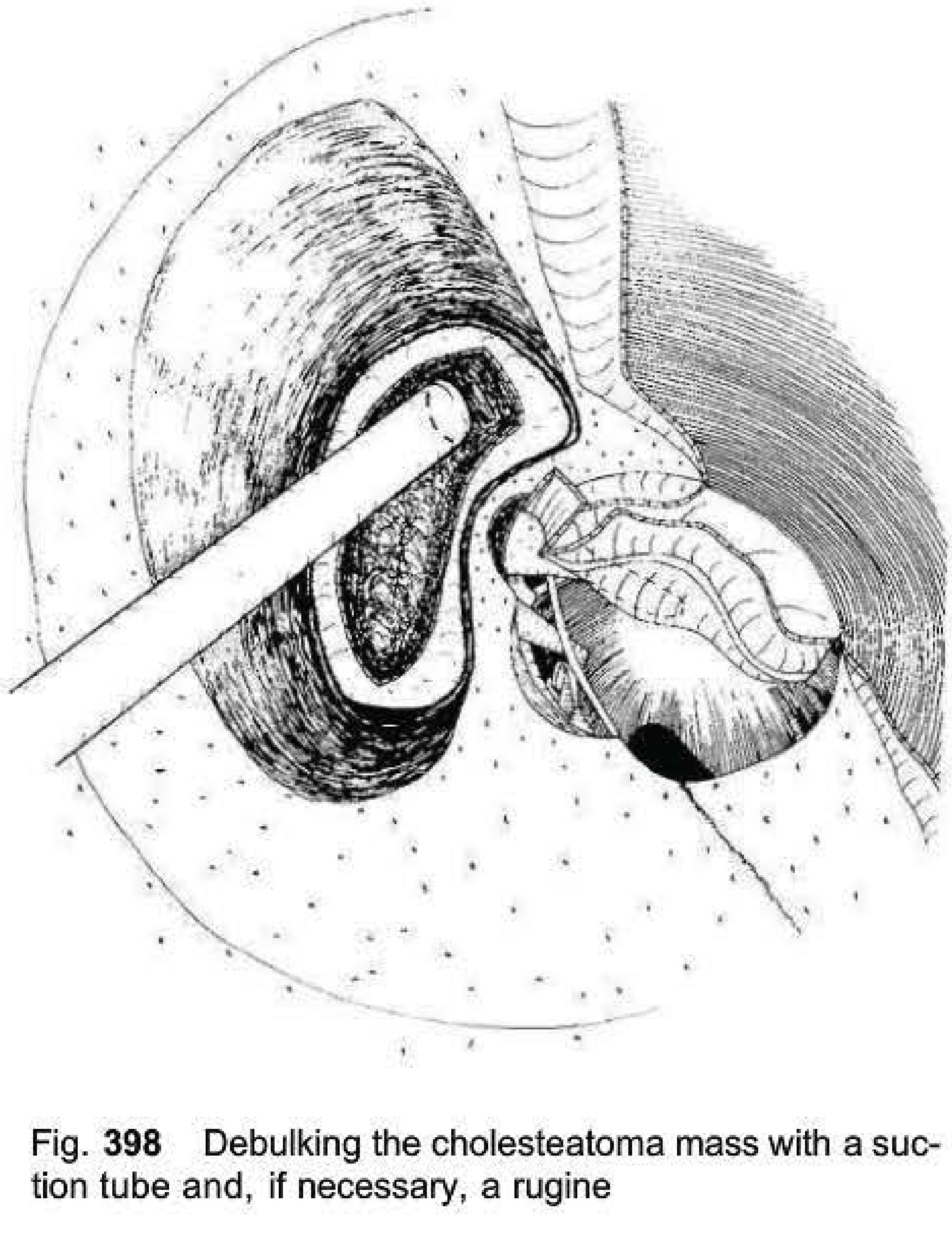


Fig. **398** Debulking the cholesteatoma mass with a suction tube and, if necessary, a rugine

cholesteatoma mass is evacuated, with a careful inspection being made of the condition of the ossicles (Fig. **398**). Debulking of the cholesteatoma is an important procedure, allowing the extent of the cholesteatoma to be established including its pockets and protrusions into the anterior attic or towards the Eustachian tube. After removal of its innermost layer (Fig. **399**), the outer matrix becomes visible, and can be elevated from the bone. The dissection of the outer matrix should be performed carefully under high magnification with gradual elevation of the entire matrix, exposing the incus body (Figs. **400, 401**). The membrane and the underlying inflammatory tissue is elevated from the incus body in such a way that the incus mucosa remains more or less intact. If necessary, the atticotomy is enlarged along the short process of the incus (Fig. **402**). The elevation of the cholesteatoma membrane continues toward the malleus head, with special care being taken to clean the inner surface of the bony bridge (Fig. **403**). Further dissection of the cholesteatoma membrane follows its extension along the superior wall of the attic, preserving the superior incudal and malleolar ligament (Fig. **404**). The cholesteatoma membrane is entirely elevated, especially from the anterior attic. The presence of cholesteatoma mem-

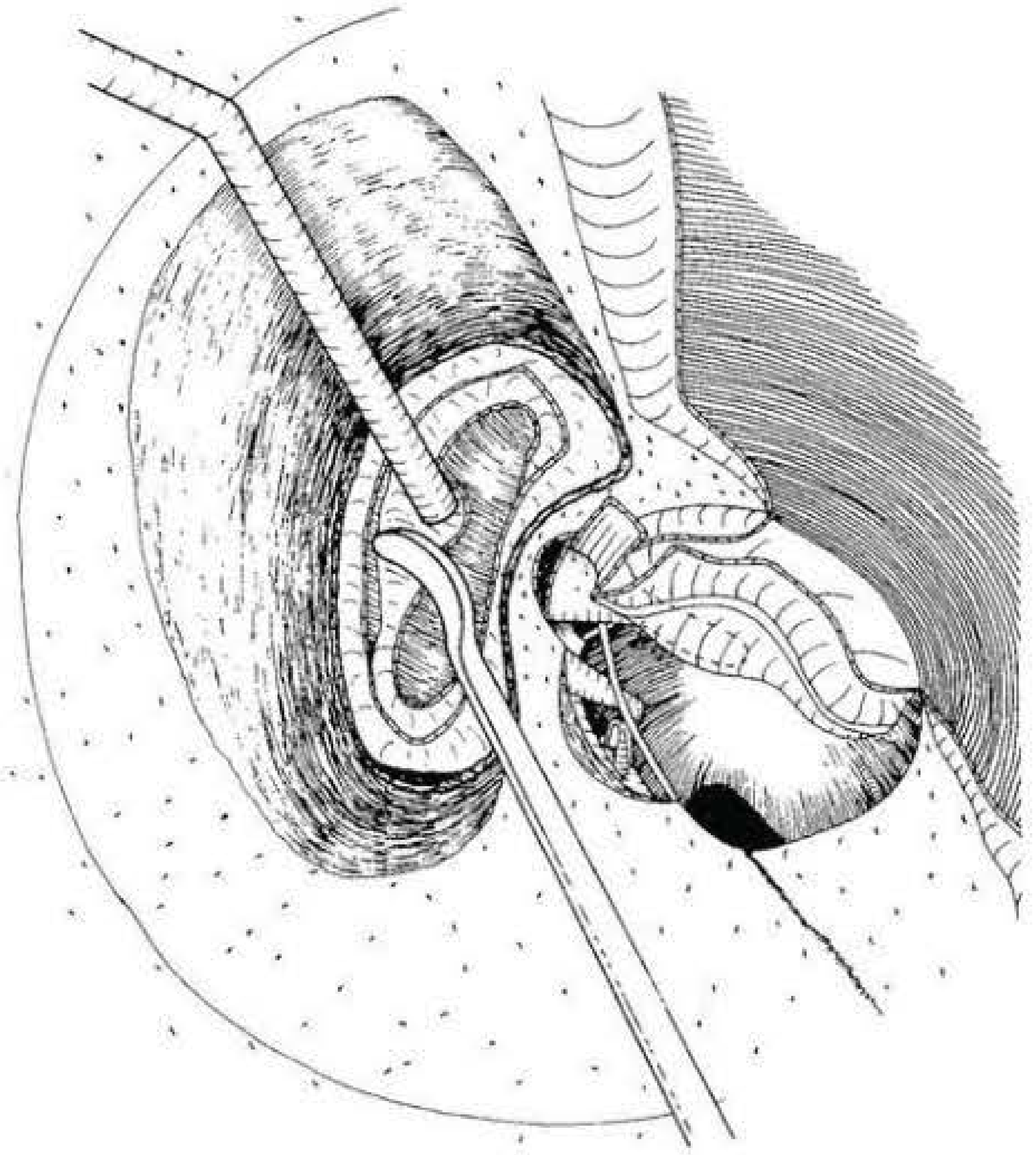


Fig. **399** Removal of one of the last cholesteatoma membranes. It is dissected away together with cholesteatoma mass from the cholesteatoma matrix

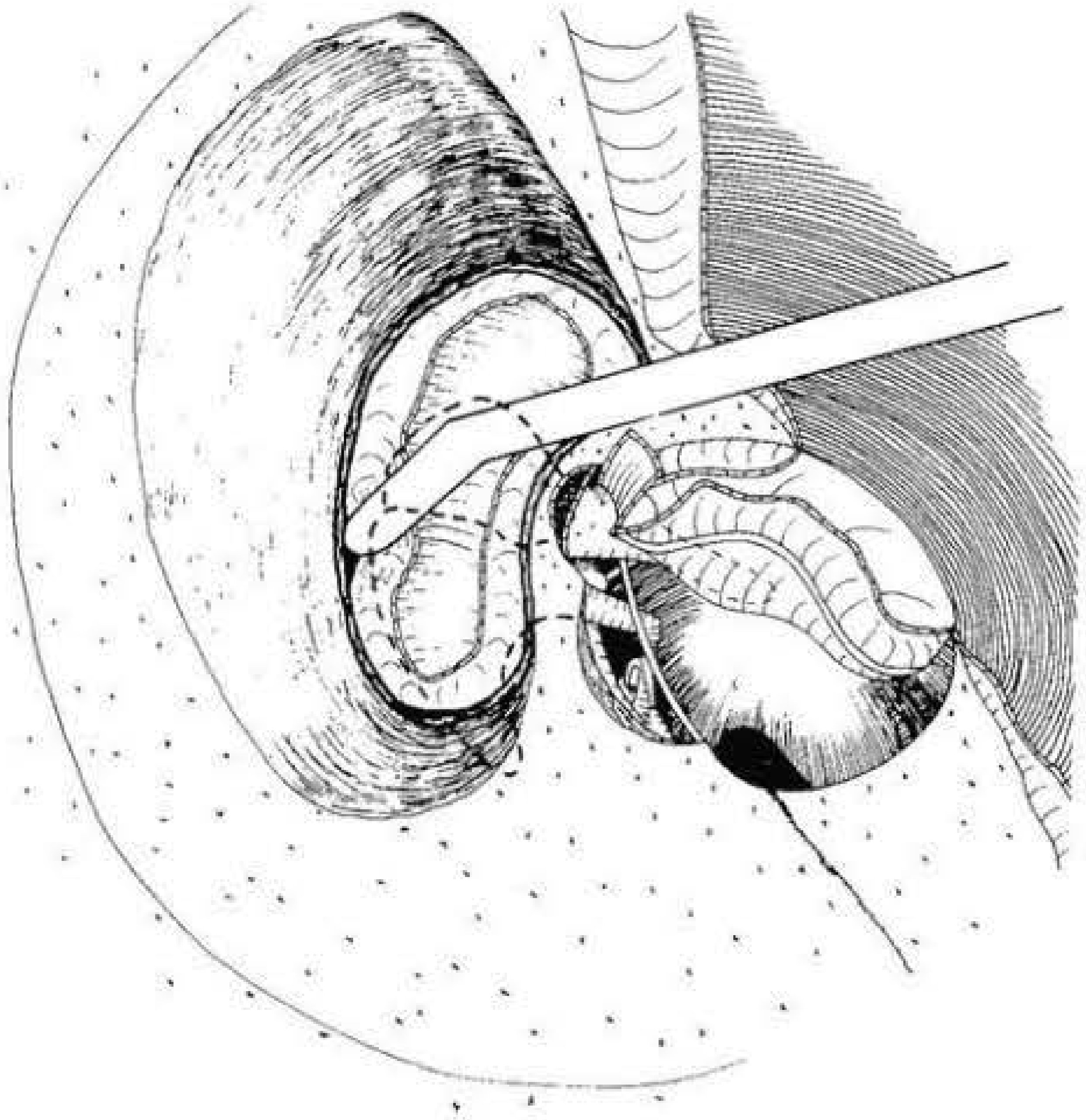


Fig. **400** The cholesteatoma matrix is attached to the ossicles and surrounding bone. It is gradually elevated from the bone

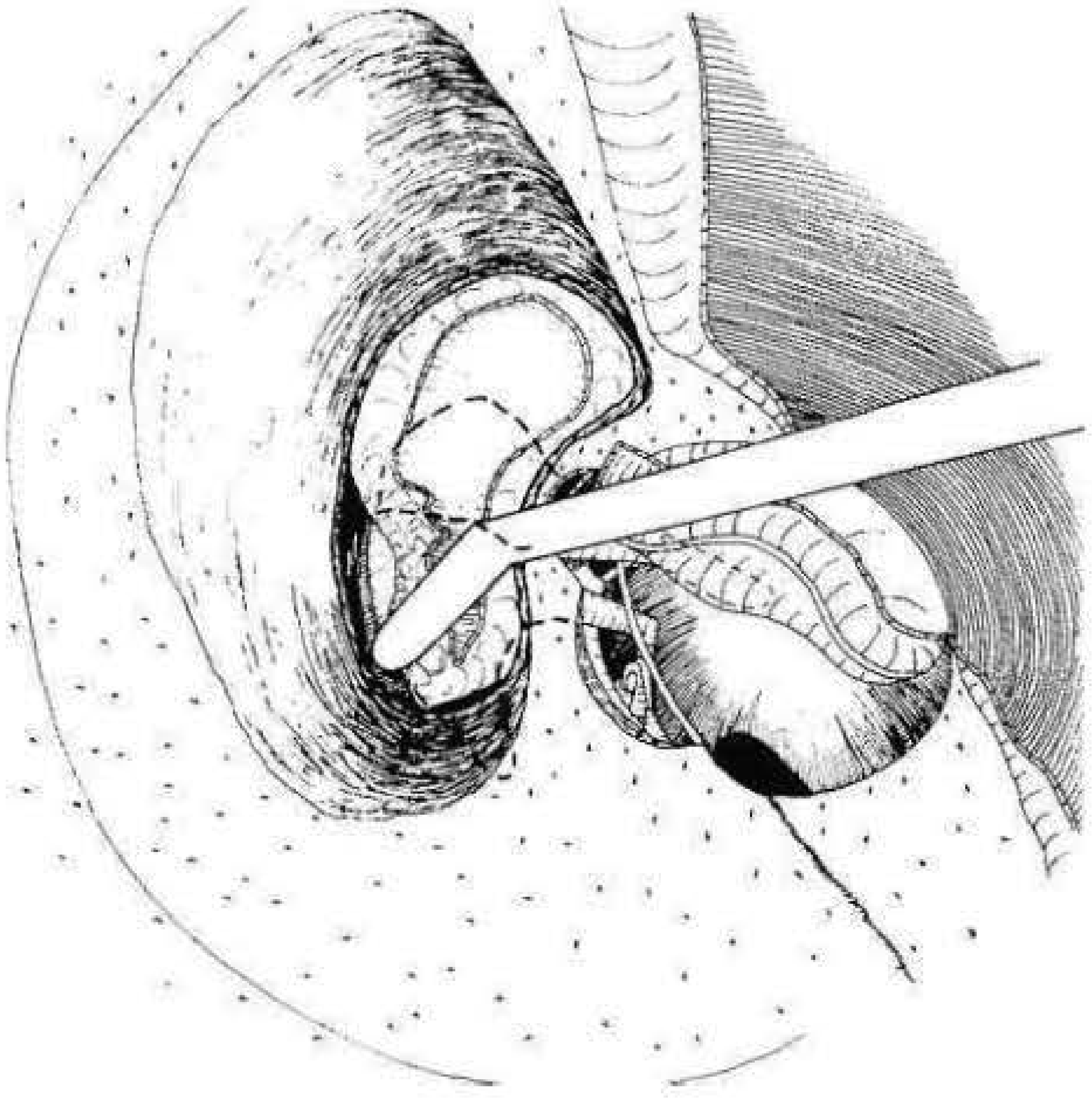


Fig. **401** The matrix is elevated from the inferior part of the attic and the incus body

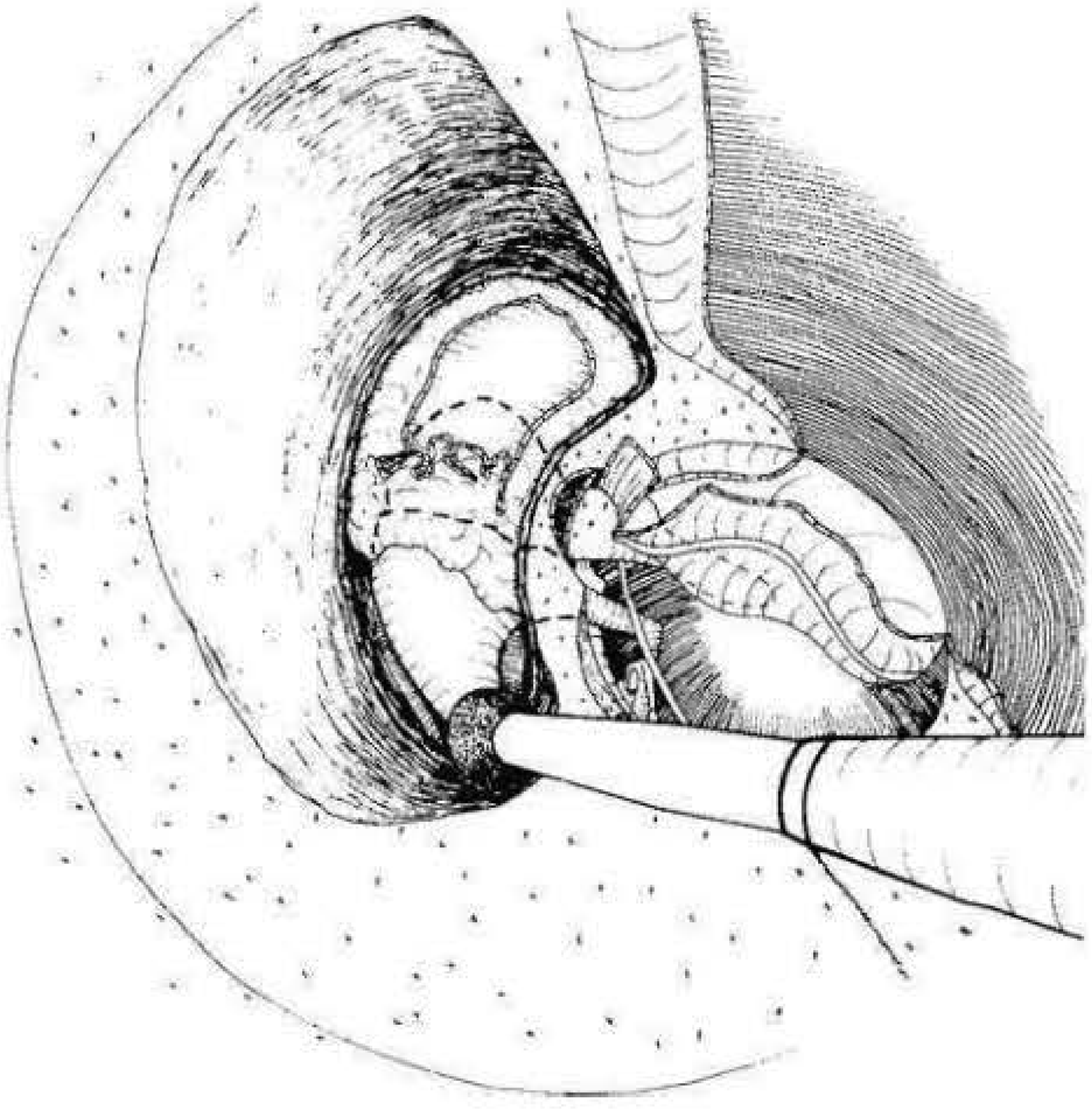


Fig. **402** The short process of the incus is exposed by enlarging the atticotomy opening toward the aditus

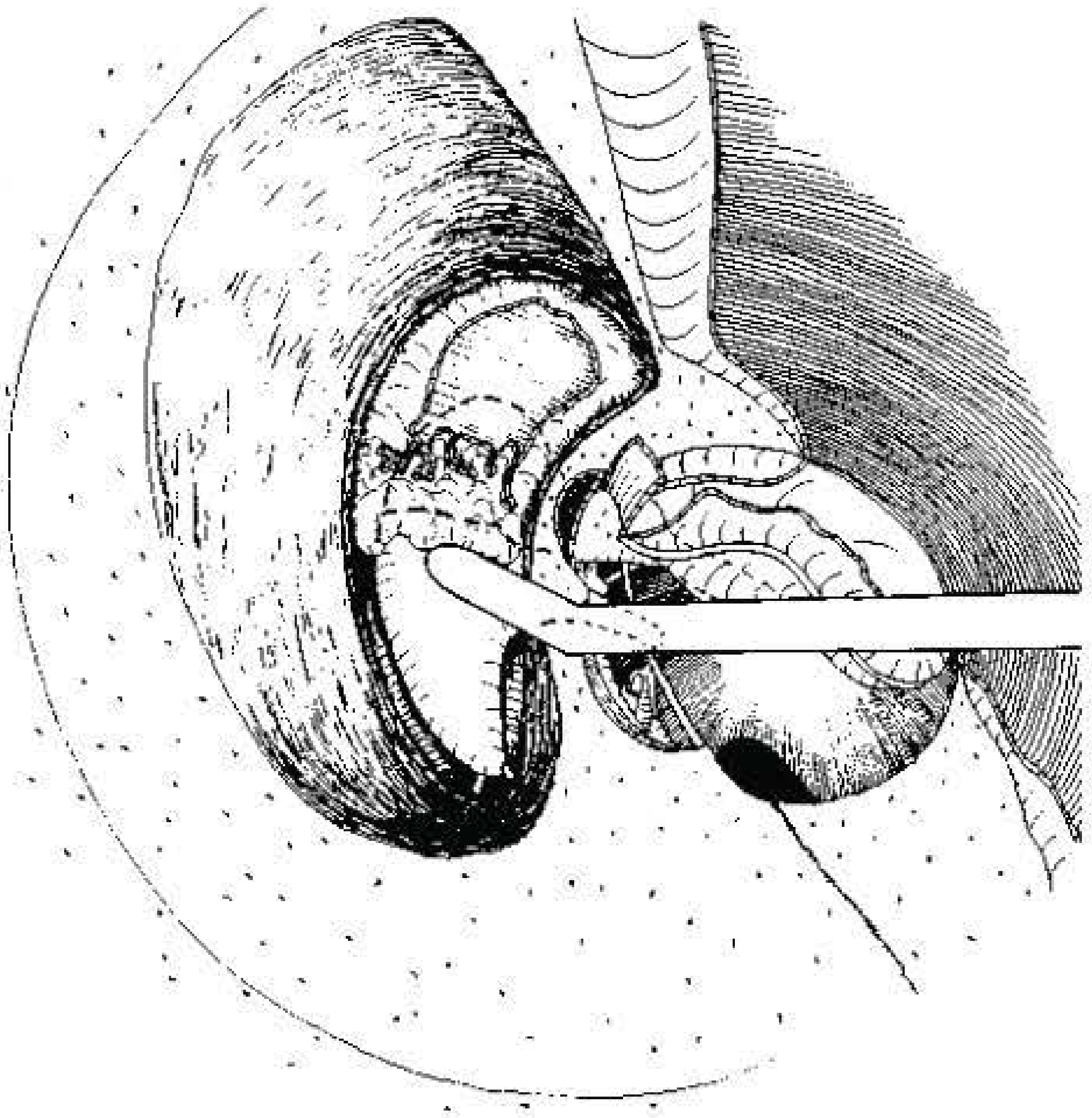


Fig. **403** Cleaning of the incus by elevating the cholesteatoma matrix

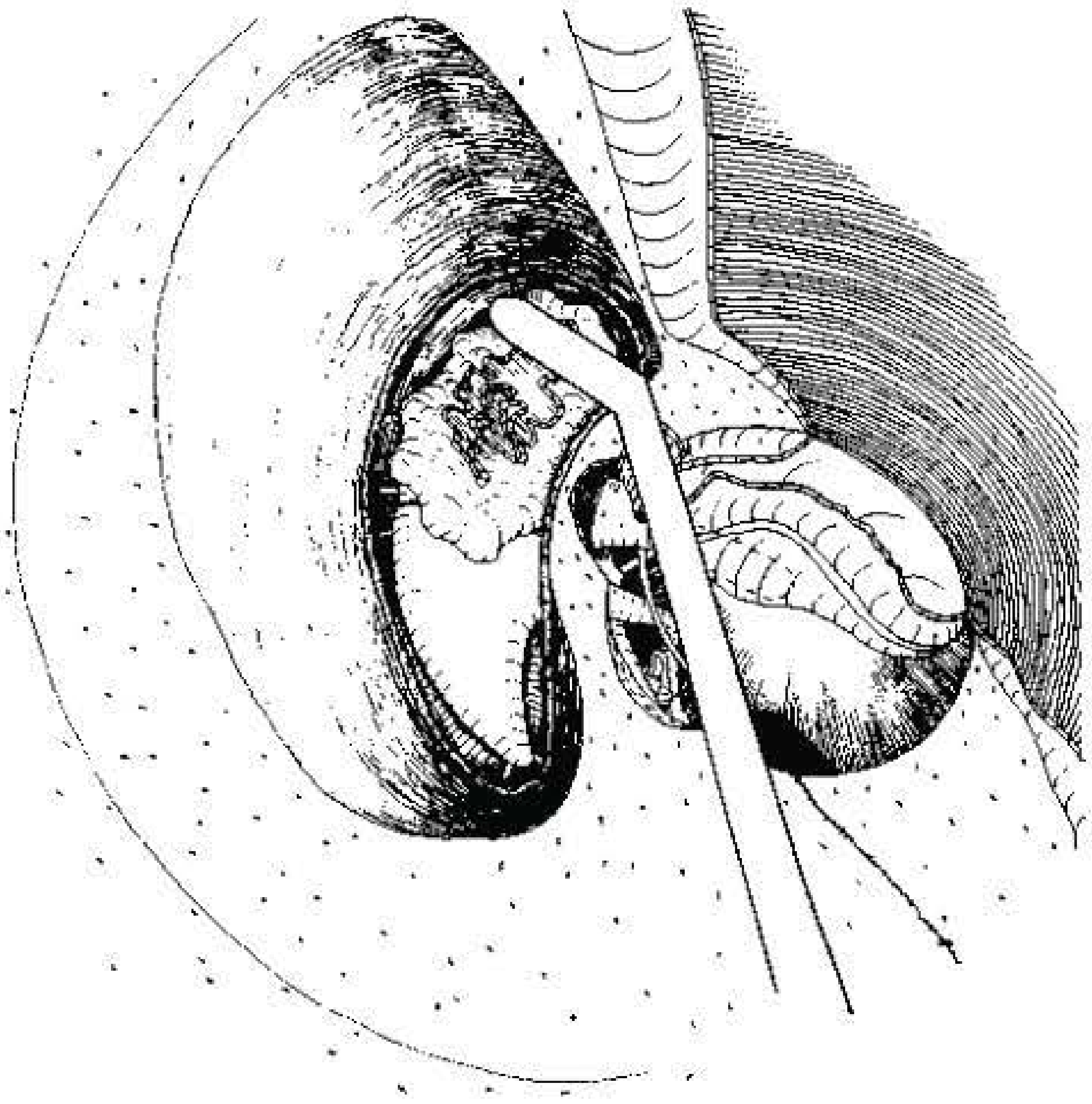


Fig. **404** Elevation of the matrix from the anterior attic

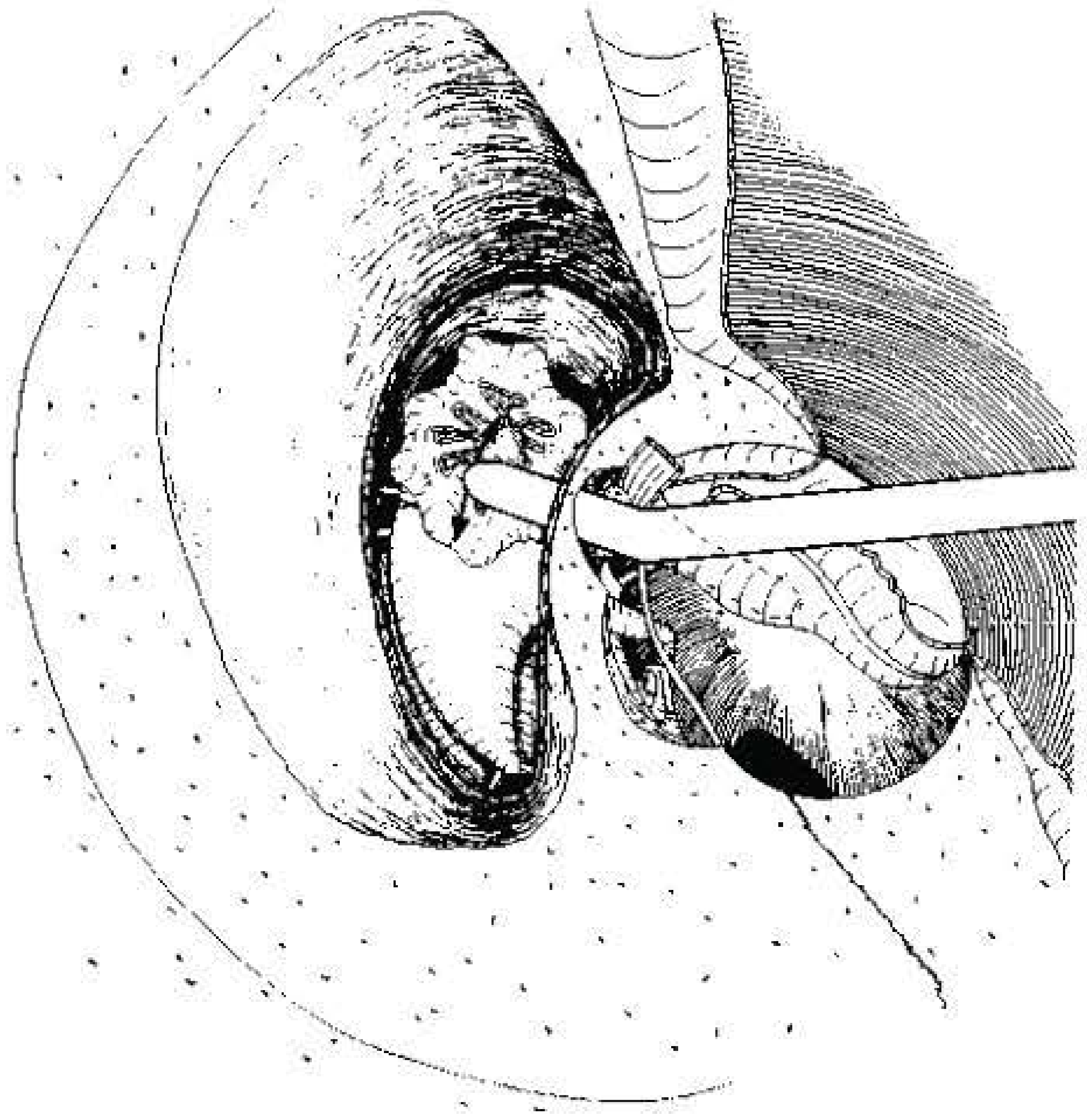


Fig. **405** The "external membrane" of the cholesteatoma neck attached to the undersurface of the bony bridge is elevated by moving a curved rugine in superior and inferior directions between the membrane and the undersurface of the bridge

brane under the bridge can be checked by moving a small curved instrument under the bridge and inspecting the elevated membrane (Figs. **405, 406**). Finally, the last part of the cholesteatoma membrane is removed (Fig. **407**), and the ossicular chain, which in many cases of small cholesteatoma will have remained intact, can be inspected.

Even if the cholesteatoma is totally removed, a cortical mastoidectomy is performed, partly in order to check the mastoid cavity for residual cholesteatoma, and partly to create a thin posterior bony ear canal wall. The reason for thinning of the posterior bony wall is that, if residual or recurrent cholesteatoma occurs in the attic, the thin bony ear canal will be gradually resorbed, and the opening to the attic will enlarge.

The mastoidectomy is performed, as described in chapters 4 and 6, by thinning the posterior ear canal wall and exenterating as many cells as necessary. Because the aim of the operation is to repneumatize the mastoid cavity, the mucosa is widely preserved, and the mastoid cells are only exenterated in order to reach the antrum (Figs. **408, 409**). After drilling of Körner's septum and further thinning of the bony ear canal wall, the antrum is entered (Fig. **410**). It is important to continue the thinning of the bony ear canal wall toward the ante-

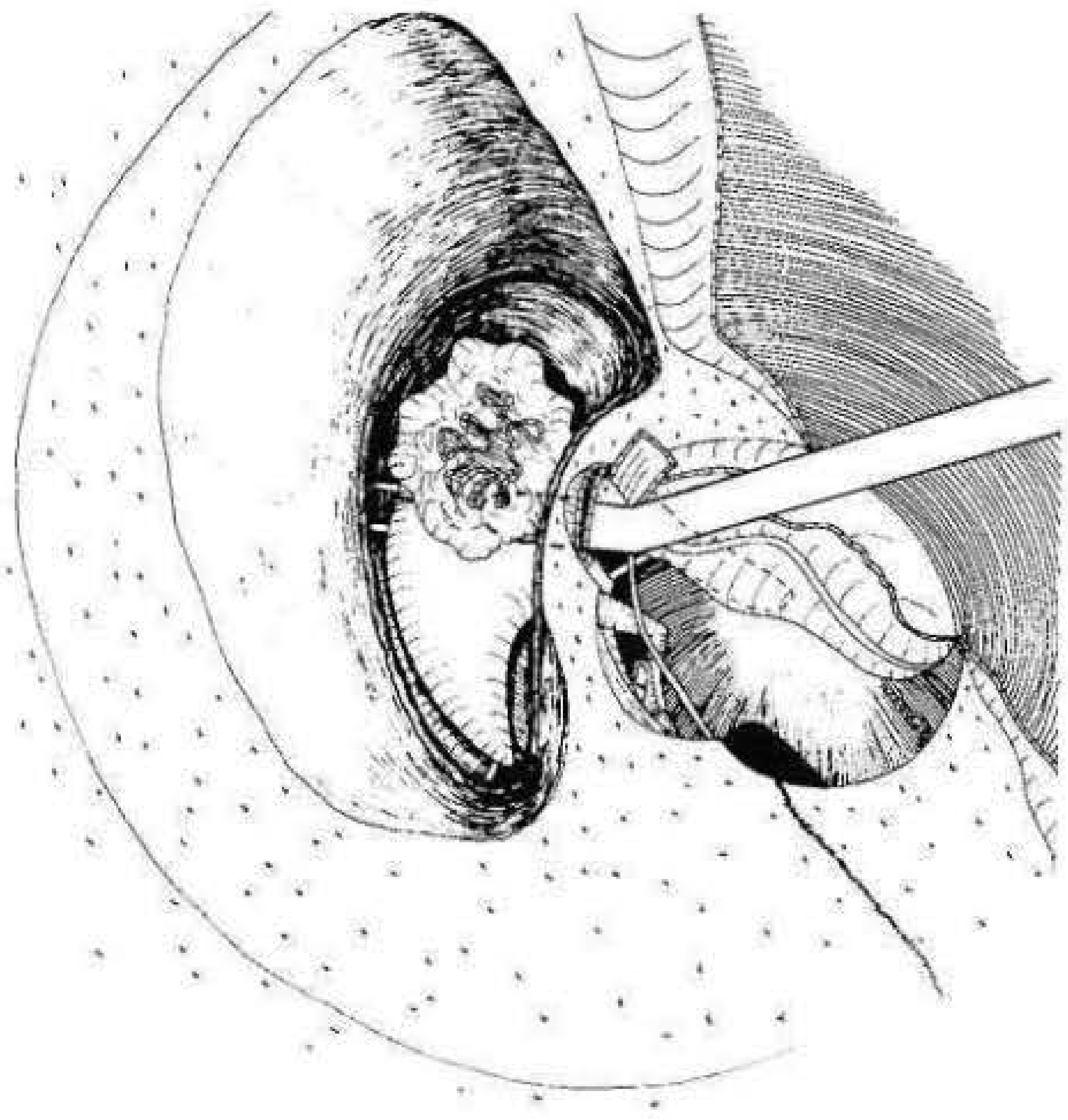


Fig. **406** Further elevation of the matrix from the malleus head. Using a curved rugine, the "internal membrane" of the cholesteatoma neck attached to the malleus head is elevated

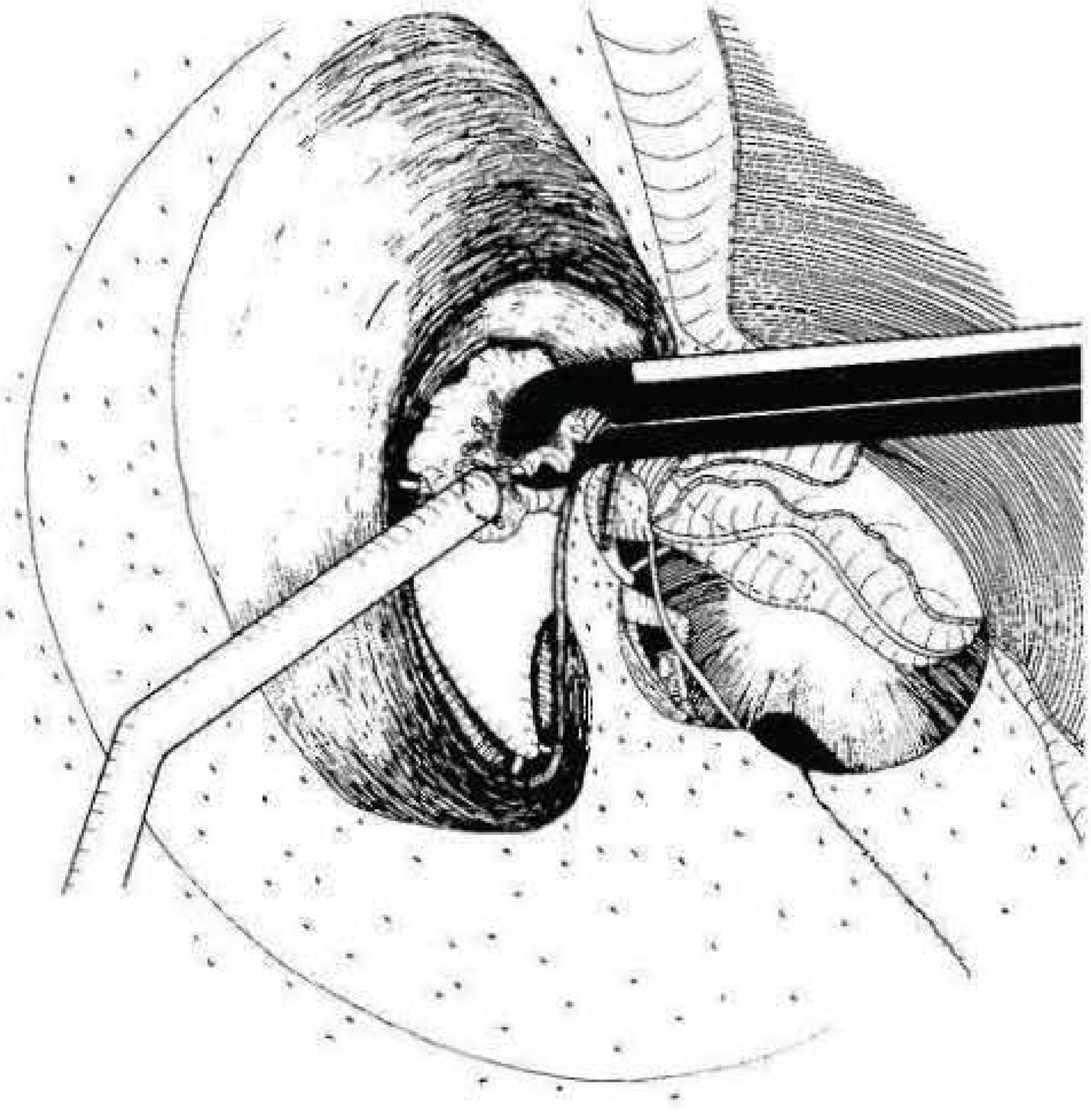
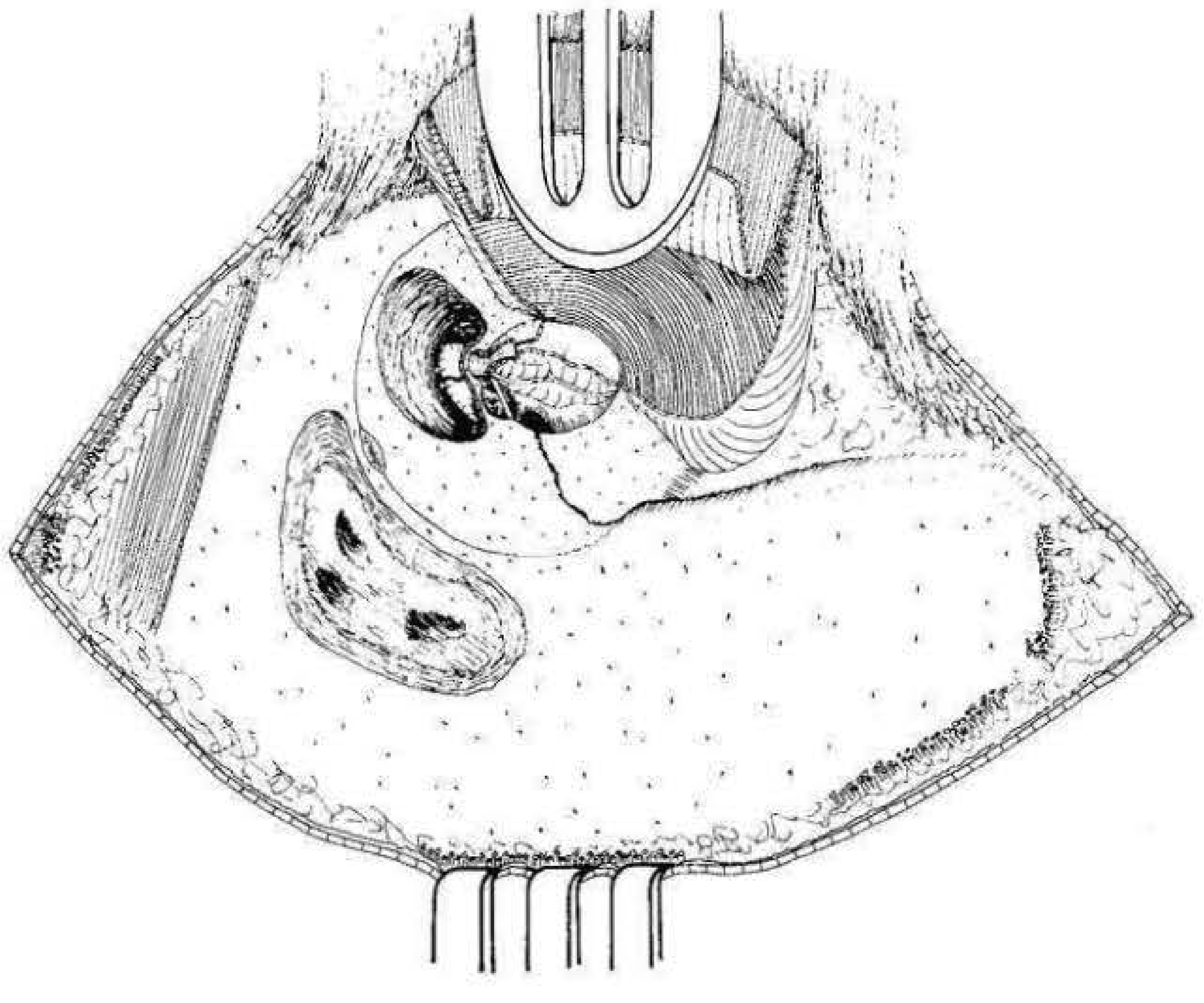


Fig. **407** Finally, all the cholesteatoma membrane is loosened from the ossicles, and this last part of the cholesteatoma matrix is removed as a bag

Fig. **408** **Intact canal wall mastoidectomy.** The drilling of the mastoid cortex starts behind the suprameatal spine



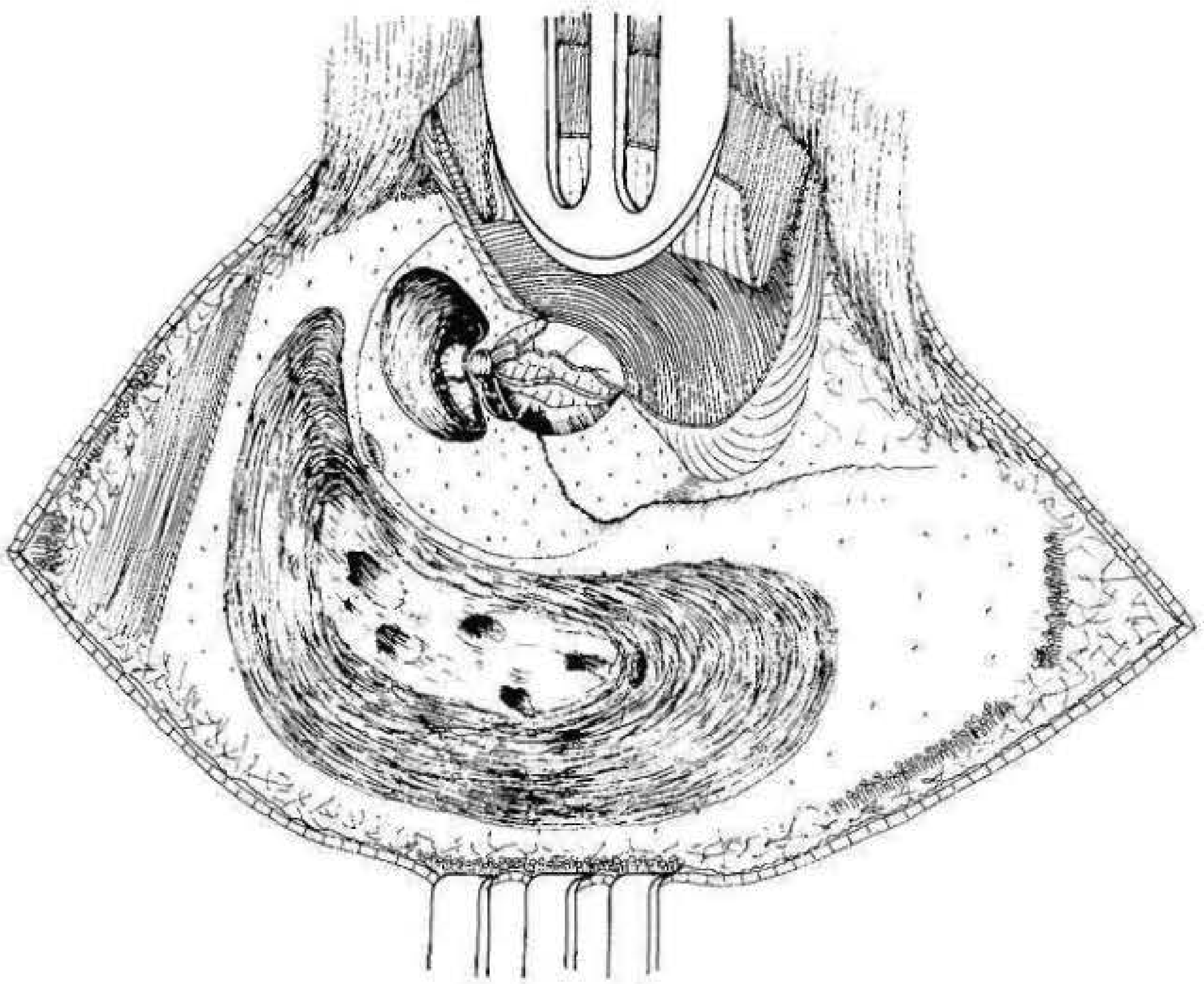


Fig. **409** The mastoid cortex is removed, and Körner's septum is visualized

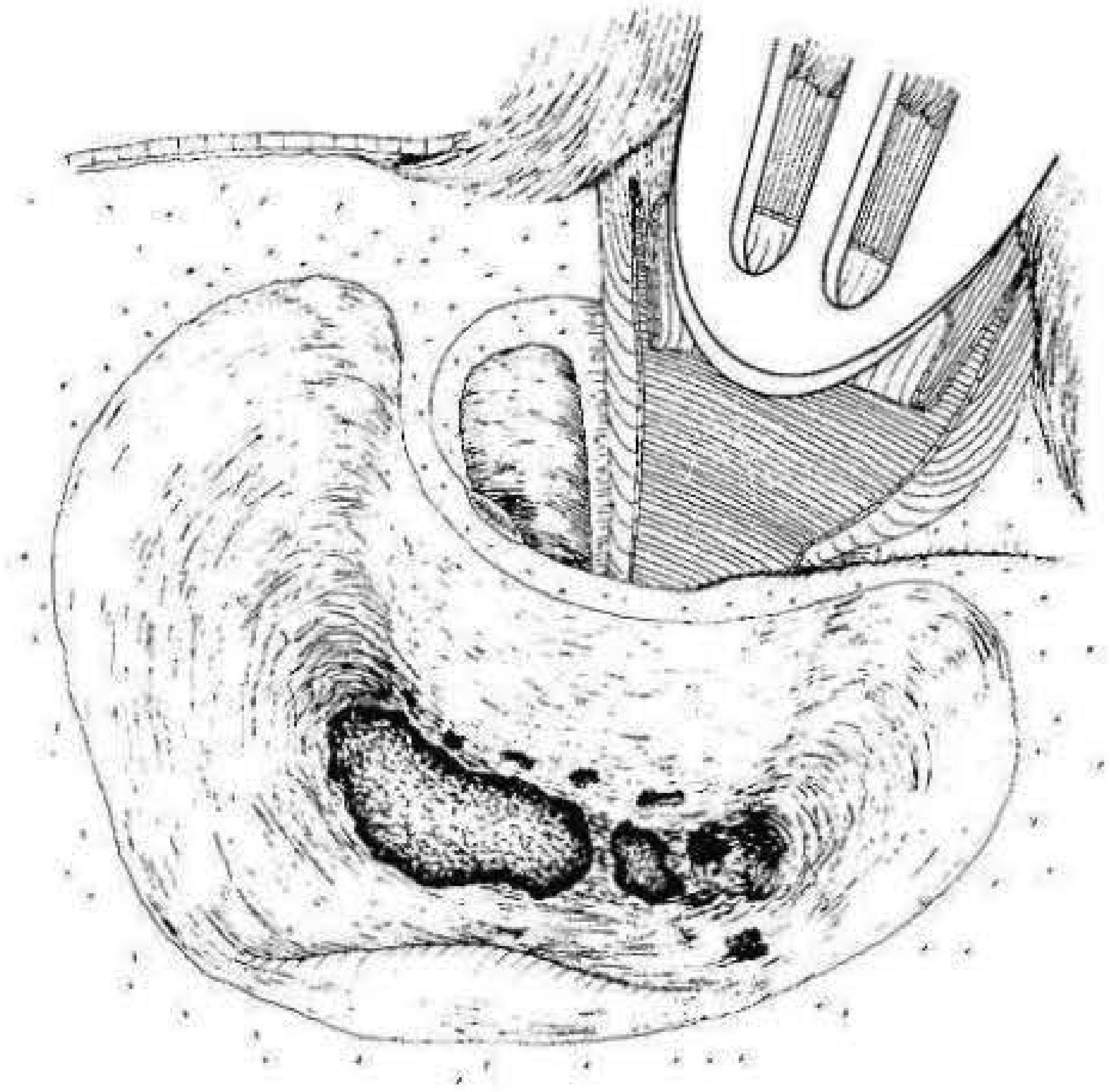


Fig. **410** Körner's septum is penetrated and the antrum exposed. The ear canal is thinned

rior attic, and this is best performed using a diamond burr (Fig. **411**). The thinning of the superior attic wall proceeds, and the position of the ossicles can be clearly inspected transmeatally, so that the drilling can be performed rapidly. Finally, the bony overhangs and the spicule of the anterior attic wall are drilled away (Fig. **412**) and the ear canal wall becomes maximally thinned (Fig. **413**). The idea of a combined approach in the author's modification is to provide an opportunity to clean the ear canal wall from the atticotomy side and the mastoidectomy side (Fig. **414**) and to clean the bridge from the atticotomy side and the tympanic cavity side (Fig. **405**). By tilting the patient anteriorly, the lateral semicircular canal and the head of the malleus, as well as the incus body, are visualized, as in classic combined-approach tympanoplasty (Fig. **415**), providing the opportunity to clean the ossicles from both sides.

In cases with cholesteatoma in the antrum and the mastoid process, removal of the bone along the mastoid tegmen and enlargement of the anterior mastoidectomy is necessary (Fig. **416**) in order to elevate the cholesteatoma membrane. However, it is still possible to clean the bony ear canal safely and accurately from both sides (Fig. **417**).

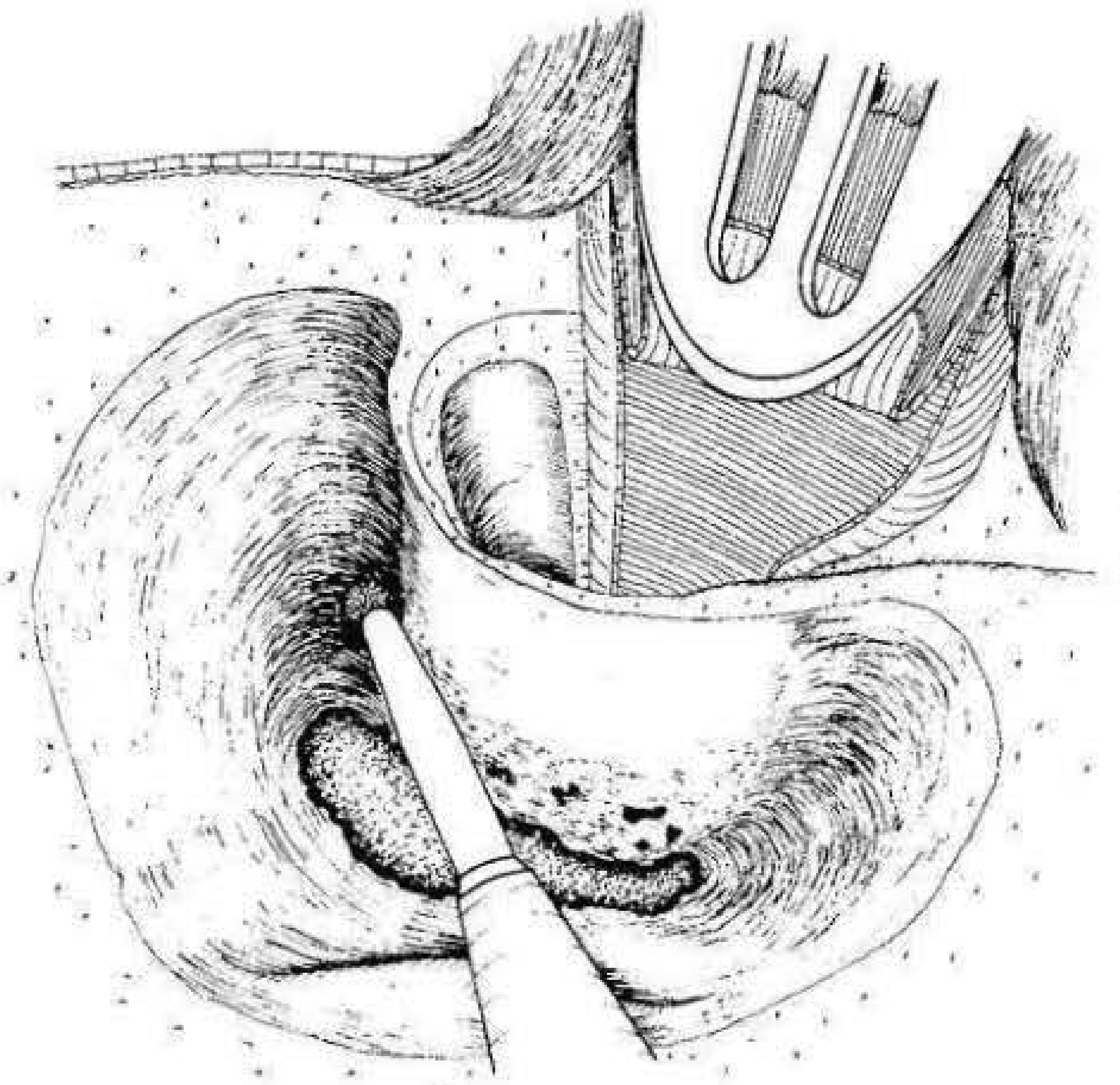


Fig. **411** The bone between the mastoid antrum and the ear canal is removed toward the zygomatic region

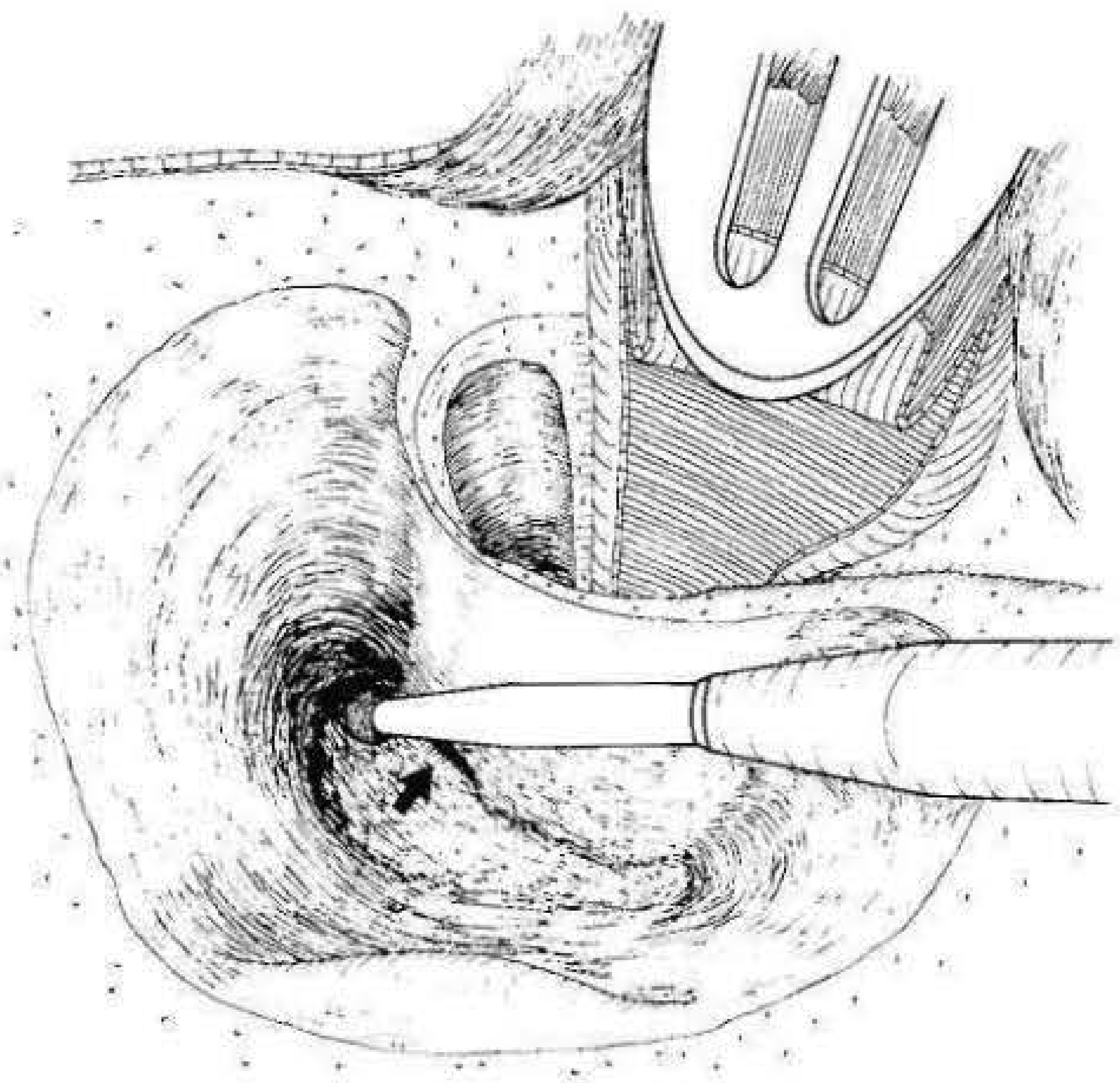


Fig. **412** Further drilling toward the zygomatic region, thinning of the posterior ear canal wall, and removal of the bony overhang covering the attic, allows exposure of the lateral semicircular canal (arrow)

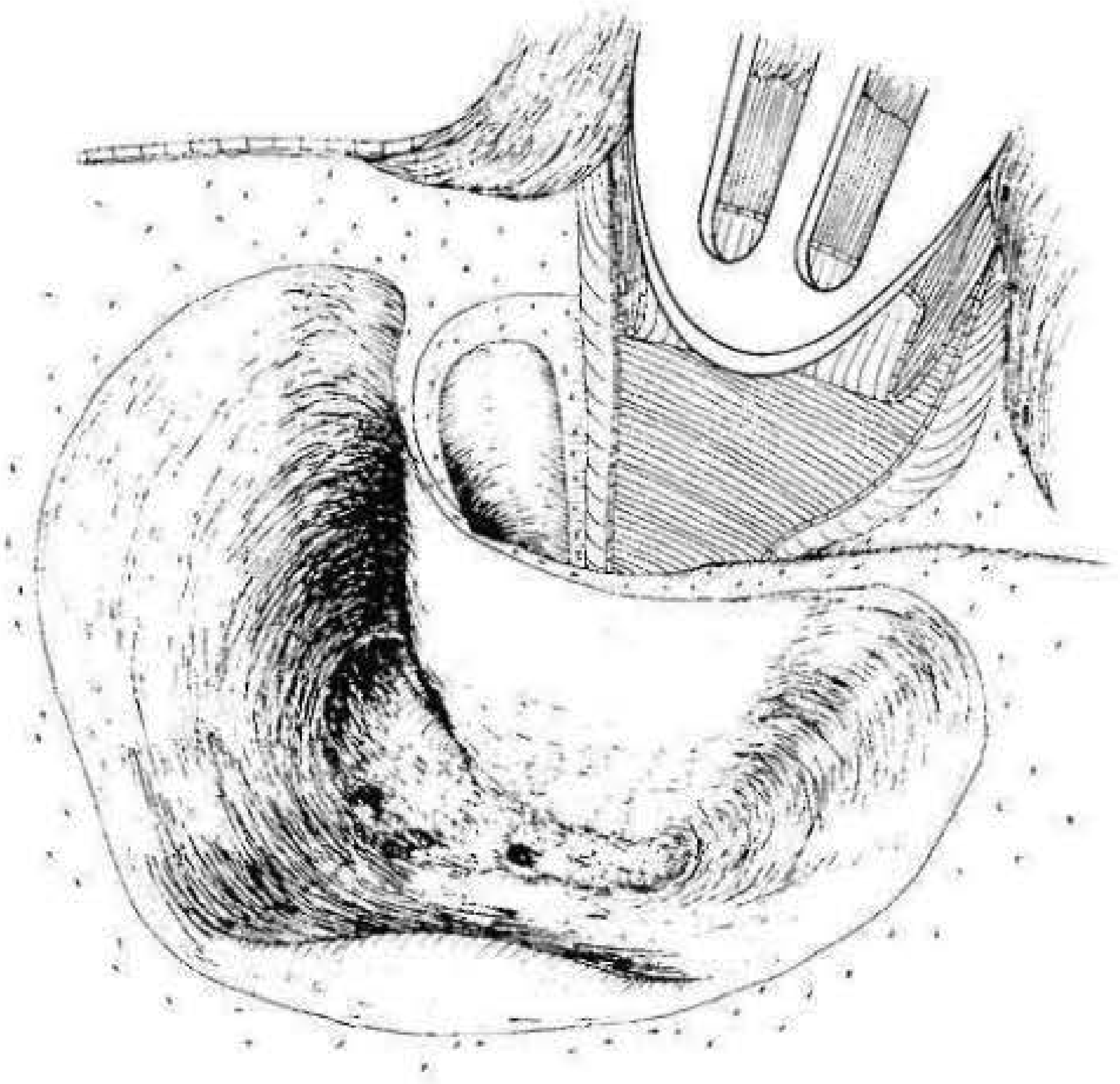


Fig. **413** The mastoidectomy is completed. The ear canal is thinned maximally, but the healthy mucosa is left in place

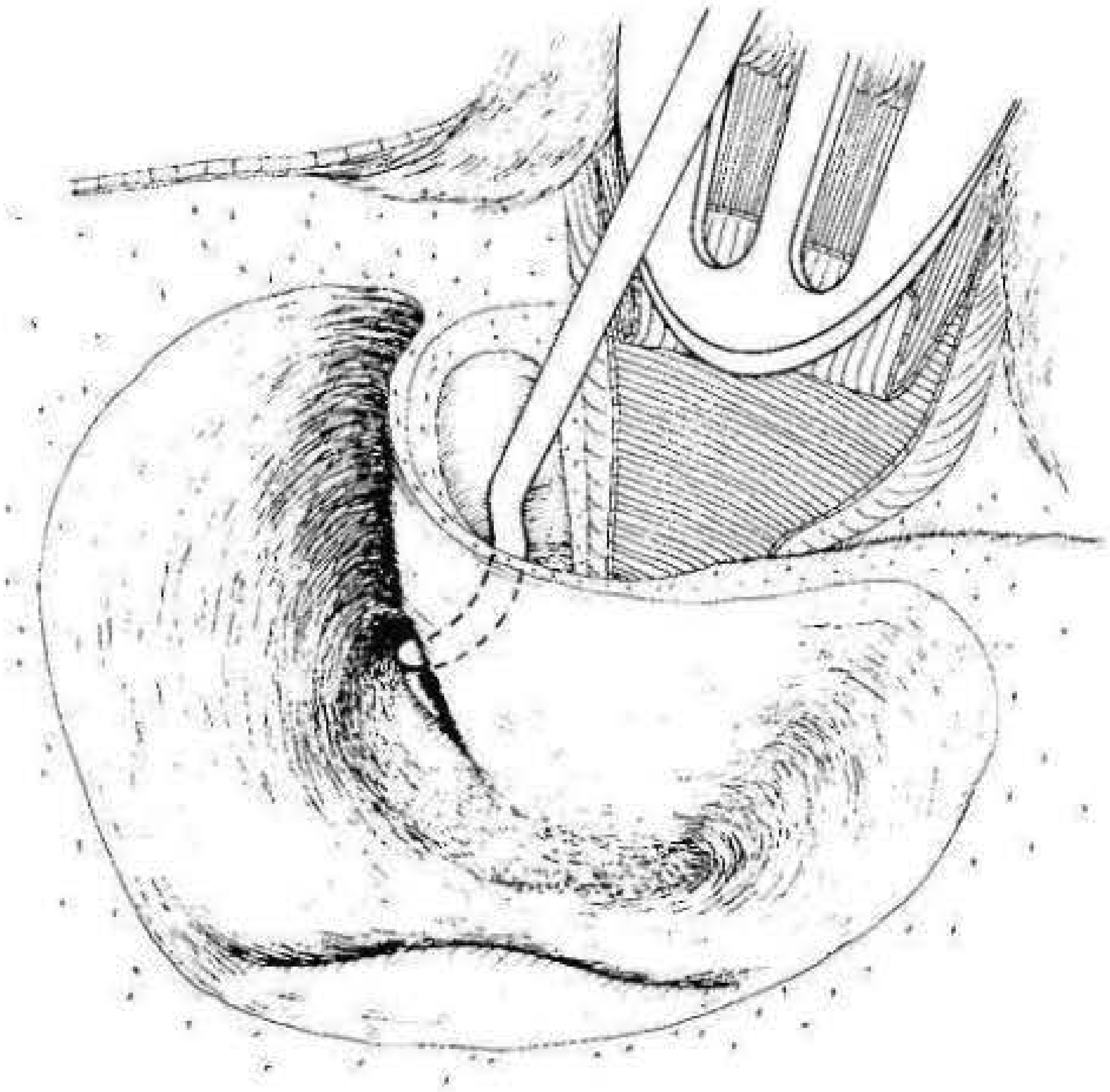


Fig. **414** Inspection and removal of any cholesteatoma remnant along the medial edge of the intact bony ear canal wall

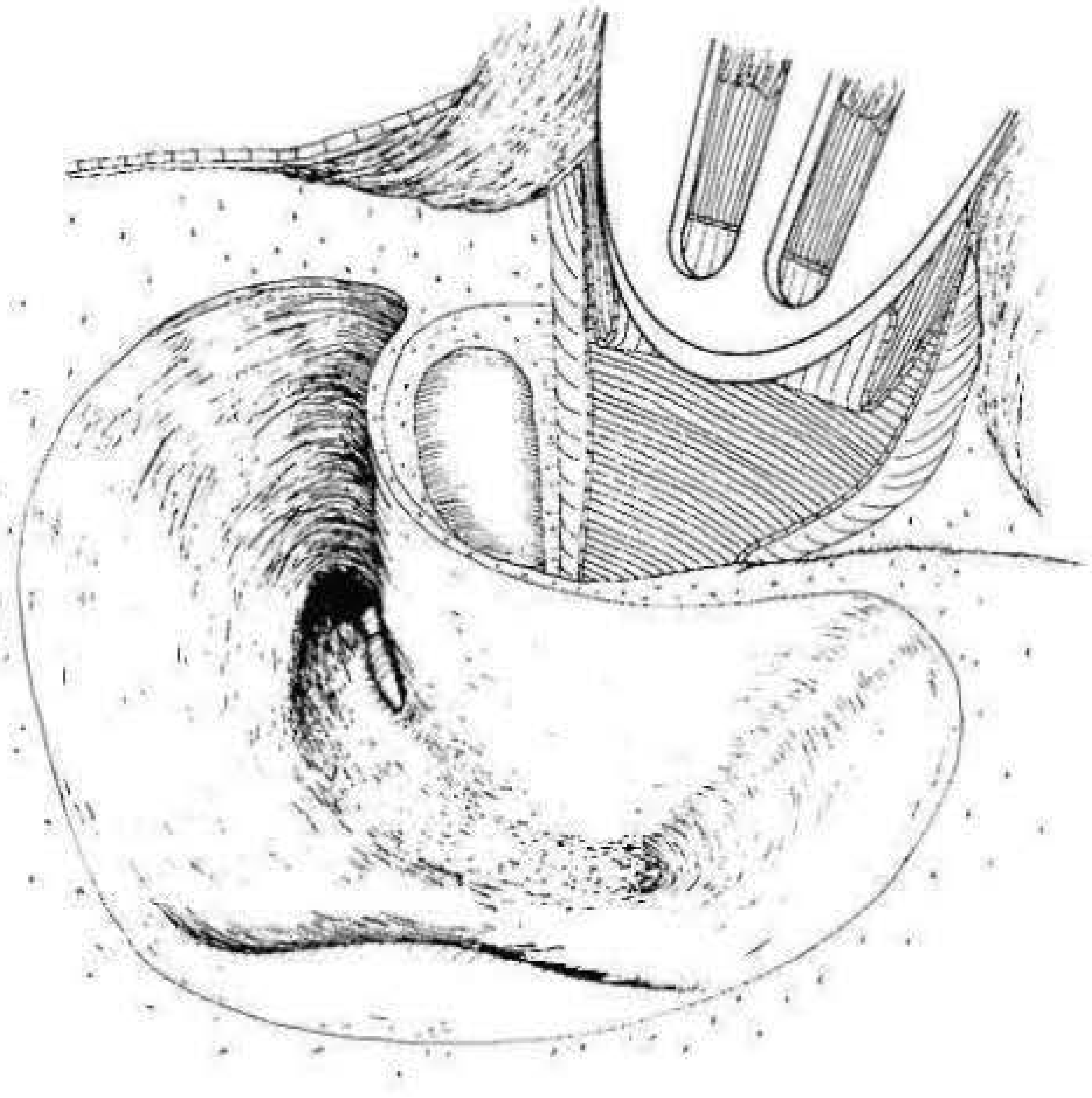


Fig. **415** When the patient is tilted anteriorly, the superior aspects of the ossicles become visible, and it can be ensured, that no cholesteatoma is left after it has been removed through the atticotomy

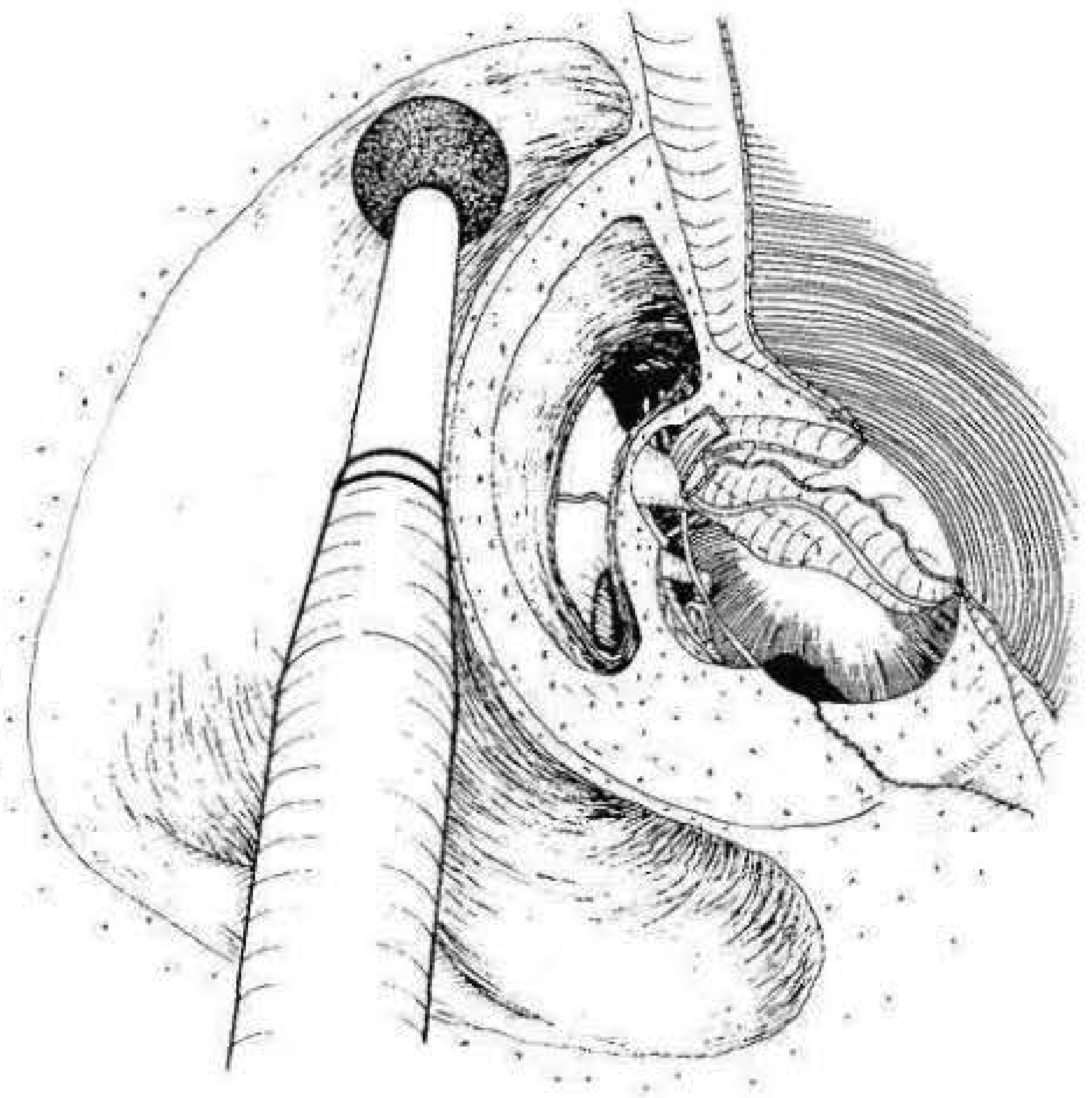


Fig. **416** Further drilling of the mastoid tegmen, enlarging the mastoid access to the anterior attic in order to perform transcortical (transmastoid) anterior atticotympanotomy

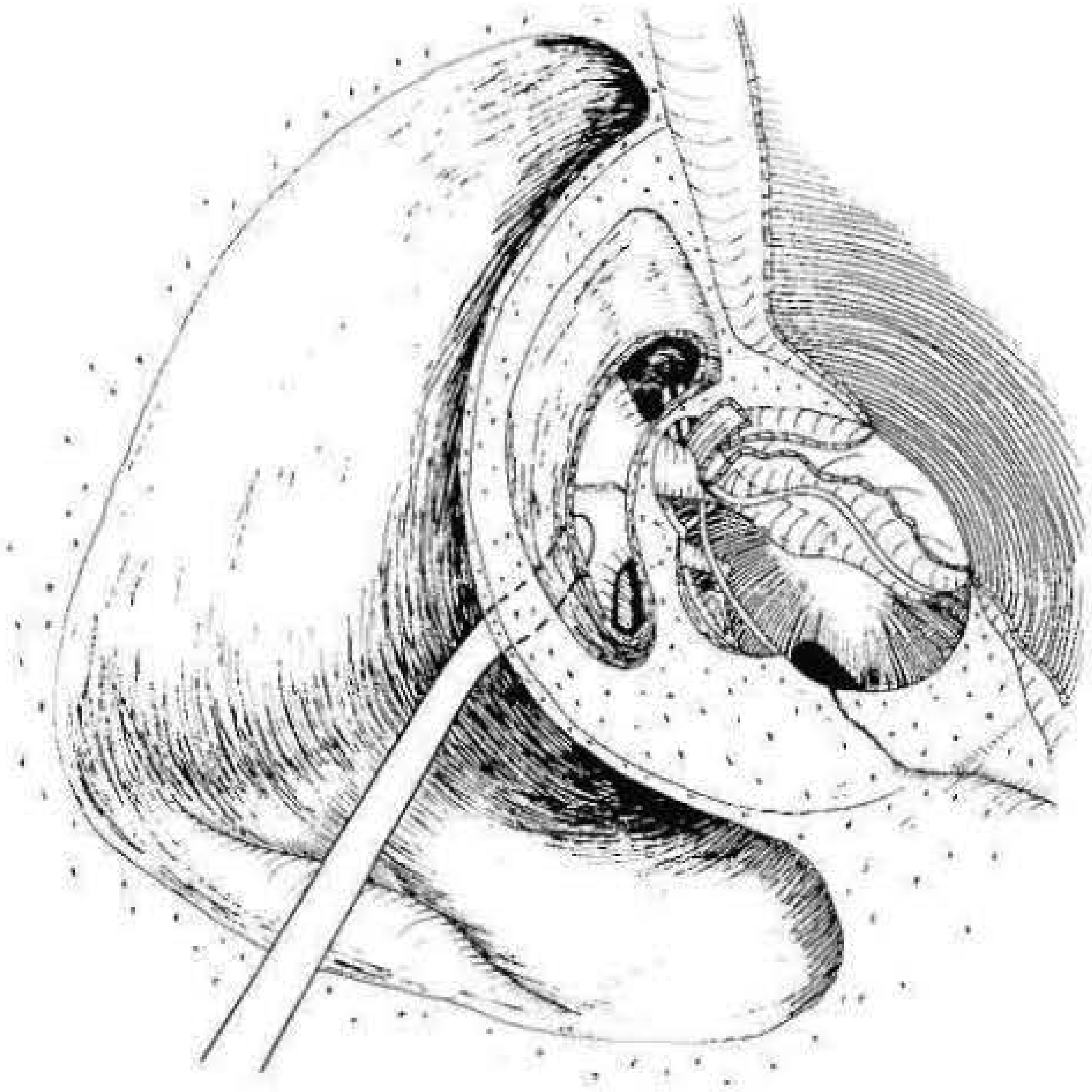


Fig. **417** The posterior edge of the intact bony ear canal wall is further inspected

Transcortical and Transmeatal Anterior Atticotympanotomy

Using this type of approach, a transcortical or transmastoid anterior atticotympanotomy can be performed in the same way as that described for classic intact canal wall mastoidectomy. By careful drilling of the bone along the tegmen tympani far anteriorly towards the anterior attic region (Fig. **418**), and by removing the bony plate between the anterior attic and epitympanic sinus (the cog), the orifice of the Eustachian tube can eventually be reached.

The transmeatal anterior atticotympanotomy can most easily be performed by careful thinning of the anterior part of the bridge and transmeatal removal of the tensor tympani muscle fold (Fig. **419**), with gradual drilling of the bone under the chorda tympani and the anterior malleolar fold (Fig. **420**), until a good communication from the Eustachian tube to the anterior attic is established (Figs. **421, 422**).

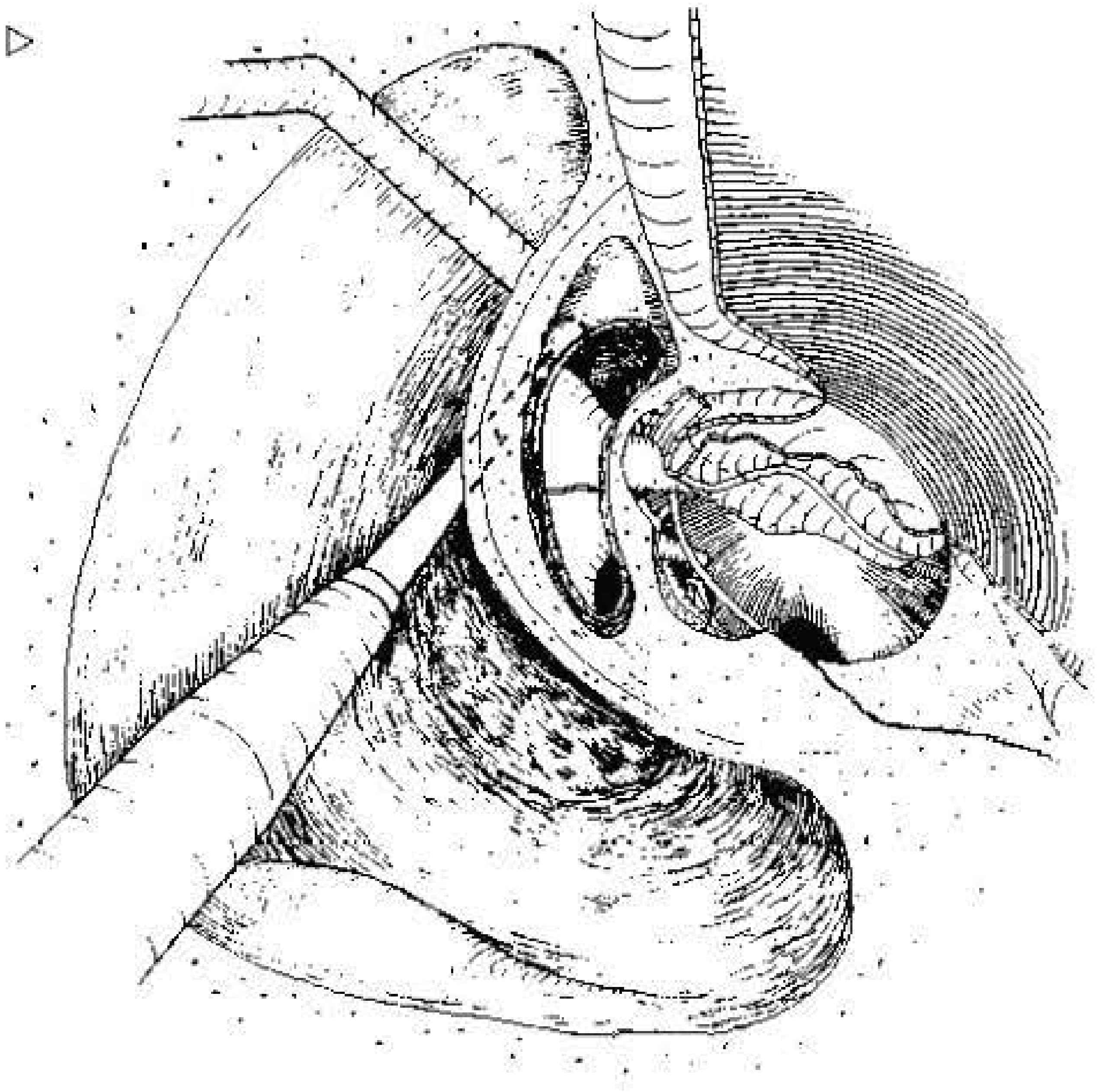
Fig. **418** **Transcortical anterior atticotympanotomy.** ▷ With a diamond burr placed through the mastoid cavity, the bony overhang covering the anterior attic is drilled away, enlarging the attic so as to be able to remove the bone separating the attic from the epitympanic sinus

Fig. **419** **Anterior tympanotomy.** The fibrous annulus is elevated between the 12-o'clock and 3-o'clock positions, and the anterior tympanic cavity is inspected. With a curved rugine placed transtympanically into the anterior attic, the tensor tympani fold, if present is torn, and a passage between the anterior attic and the mesotympanum is established

Fig. **420** **Transmeatal anterior atticotympanotomy.** Further drilling of the bone from the attic wall and thinning of the bridge, enlarging the access for the anterior atticotympanotomy

Fig. **421** A curved rugine is placed under the chorda tympani and the anterior mallear fold, and the connection to the tympanic cavity is further established

Fig. **422** The curved rugine is placed under the chorda tympani, through the epitympanic recess, and into the orifice of the Eustachian tube



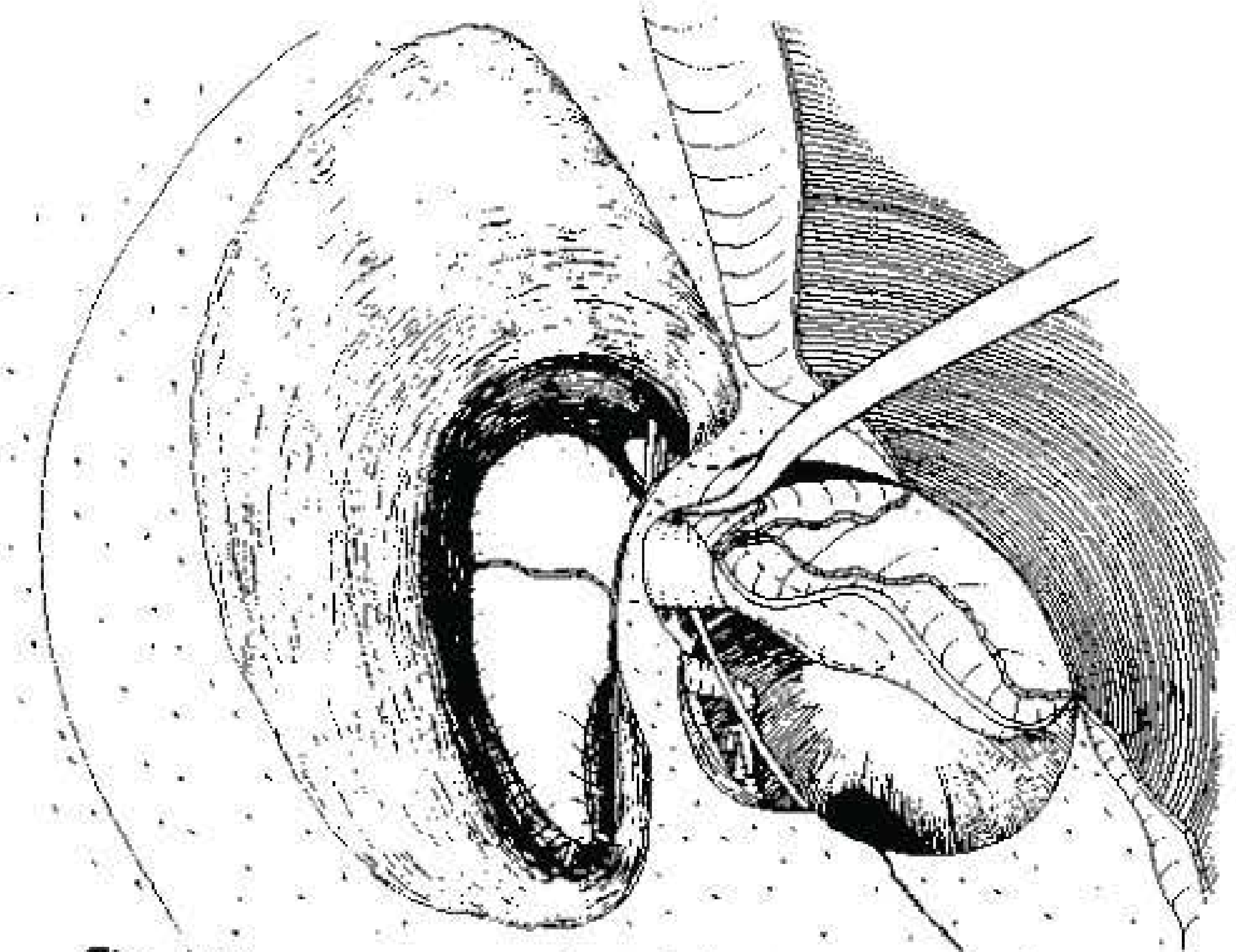


Fig. **419**

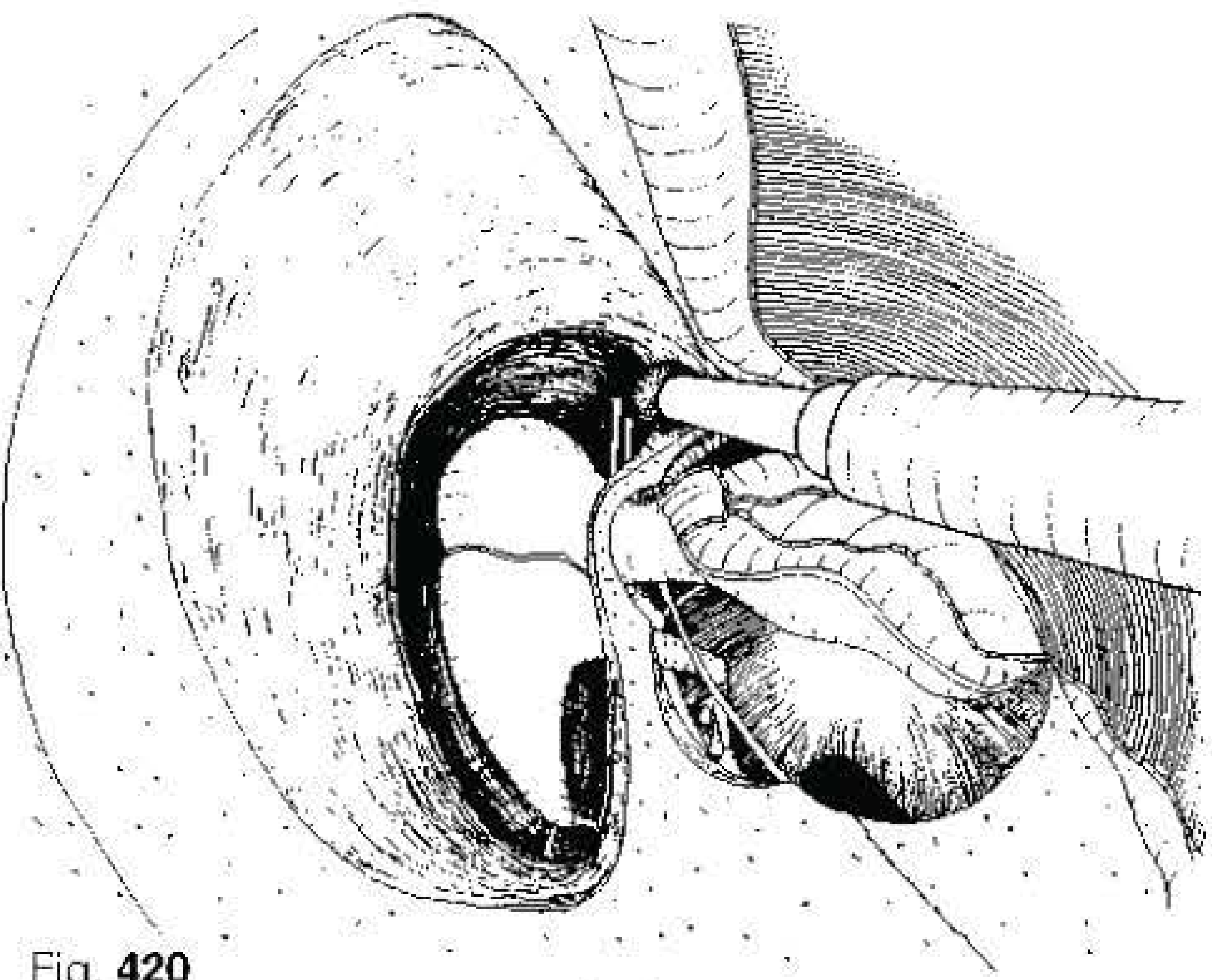


Fig. **420**

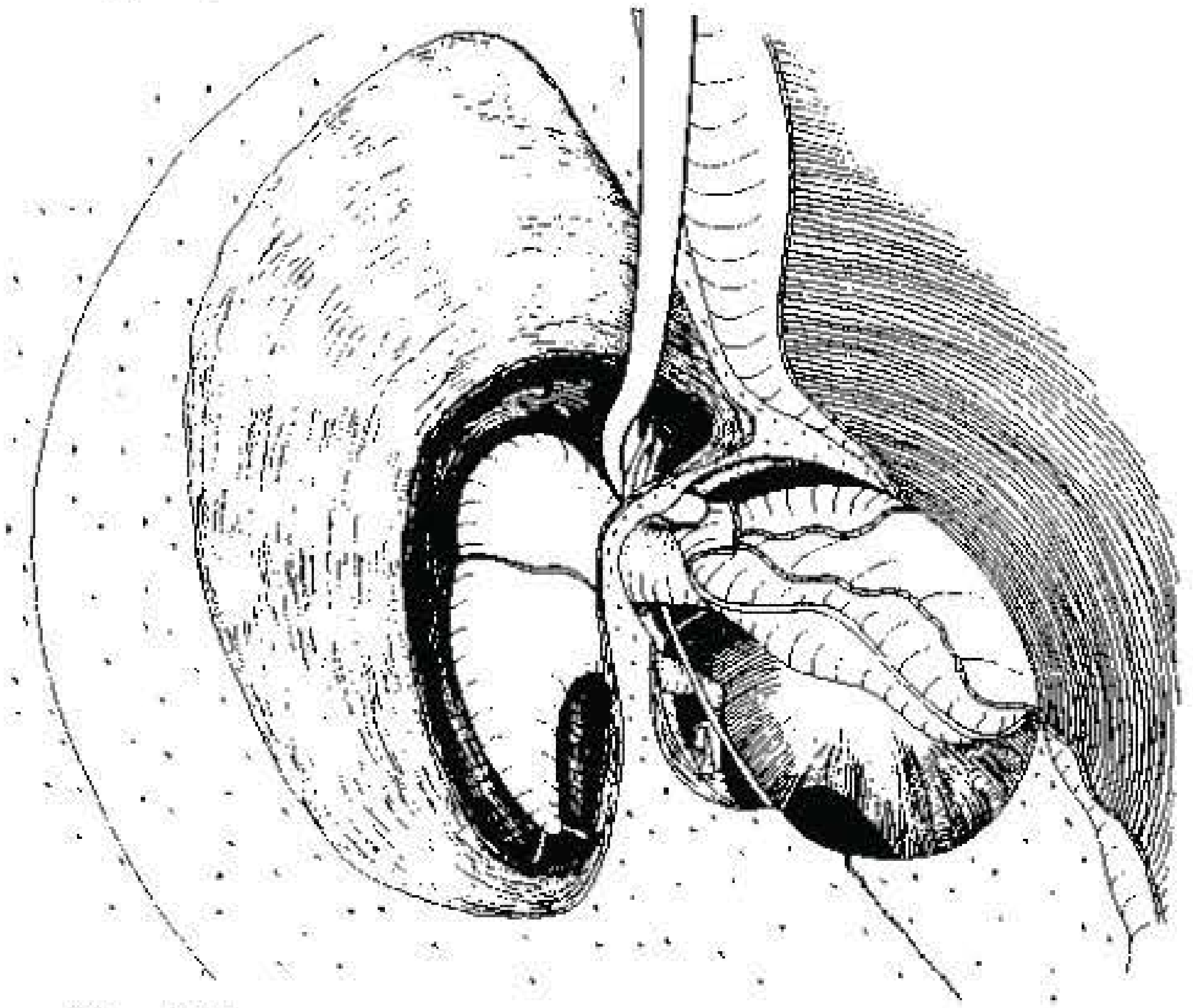


Fig. **421**

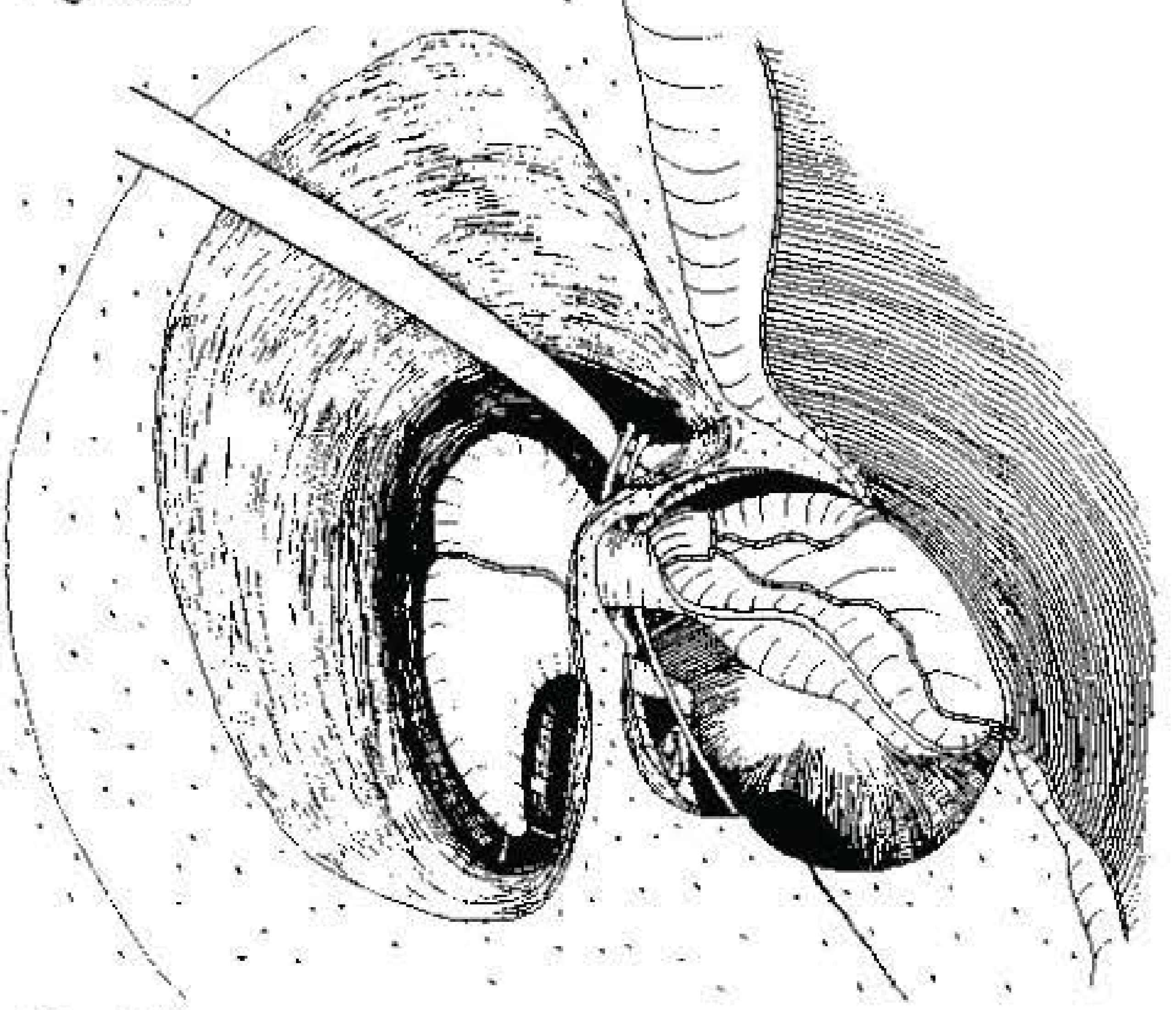


Fig. **422**

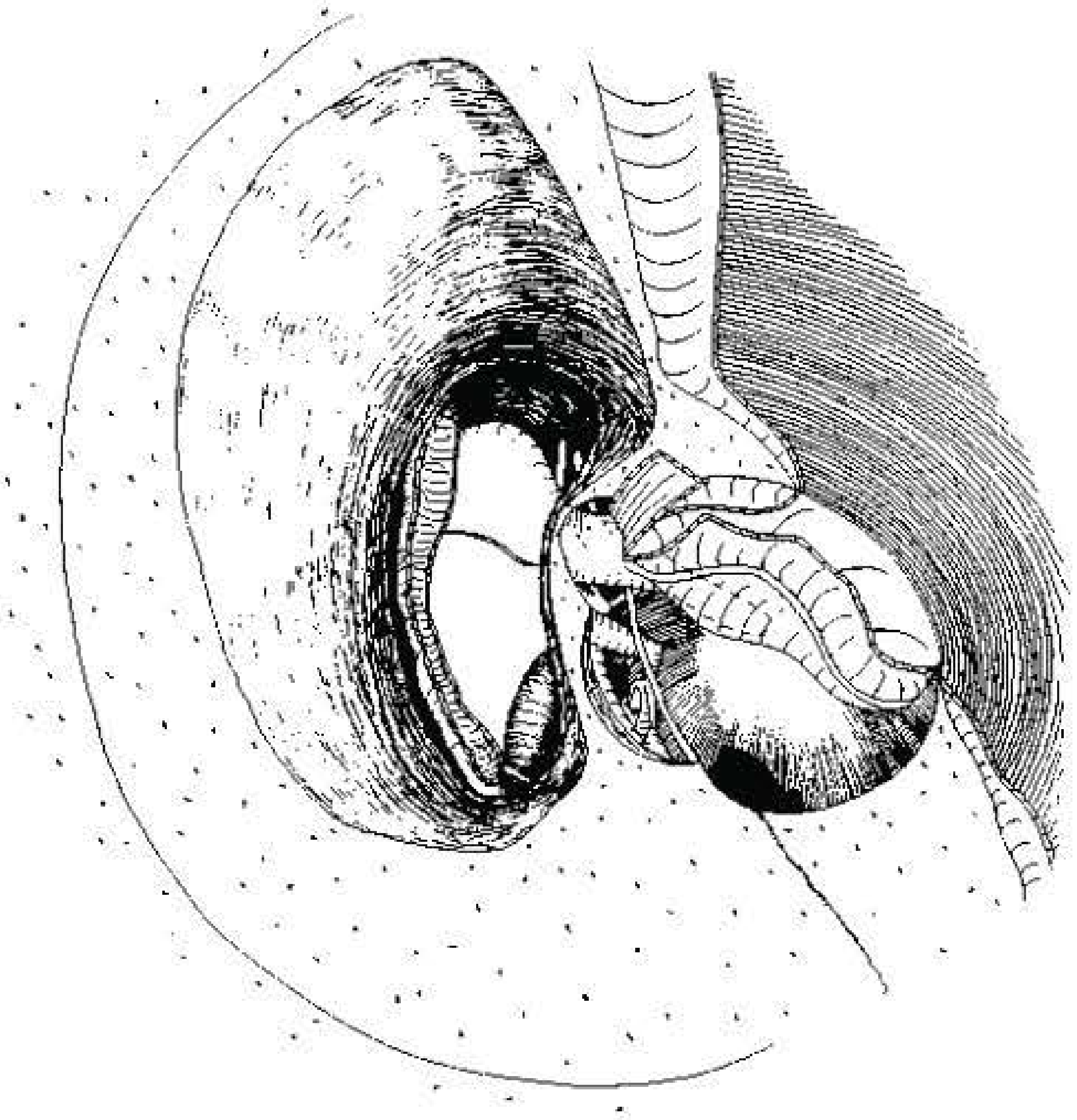


Fig. **423** **Removal of large attic cholesteatoma.** After otosclerosis drilling and atticotomy, the cholesteatoma from the anterior attic, the tympanic sinus, and the lateral attic is removed, preserving the ossicular chain intact. The cholesteatoma continuing into the antrum is left in place

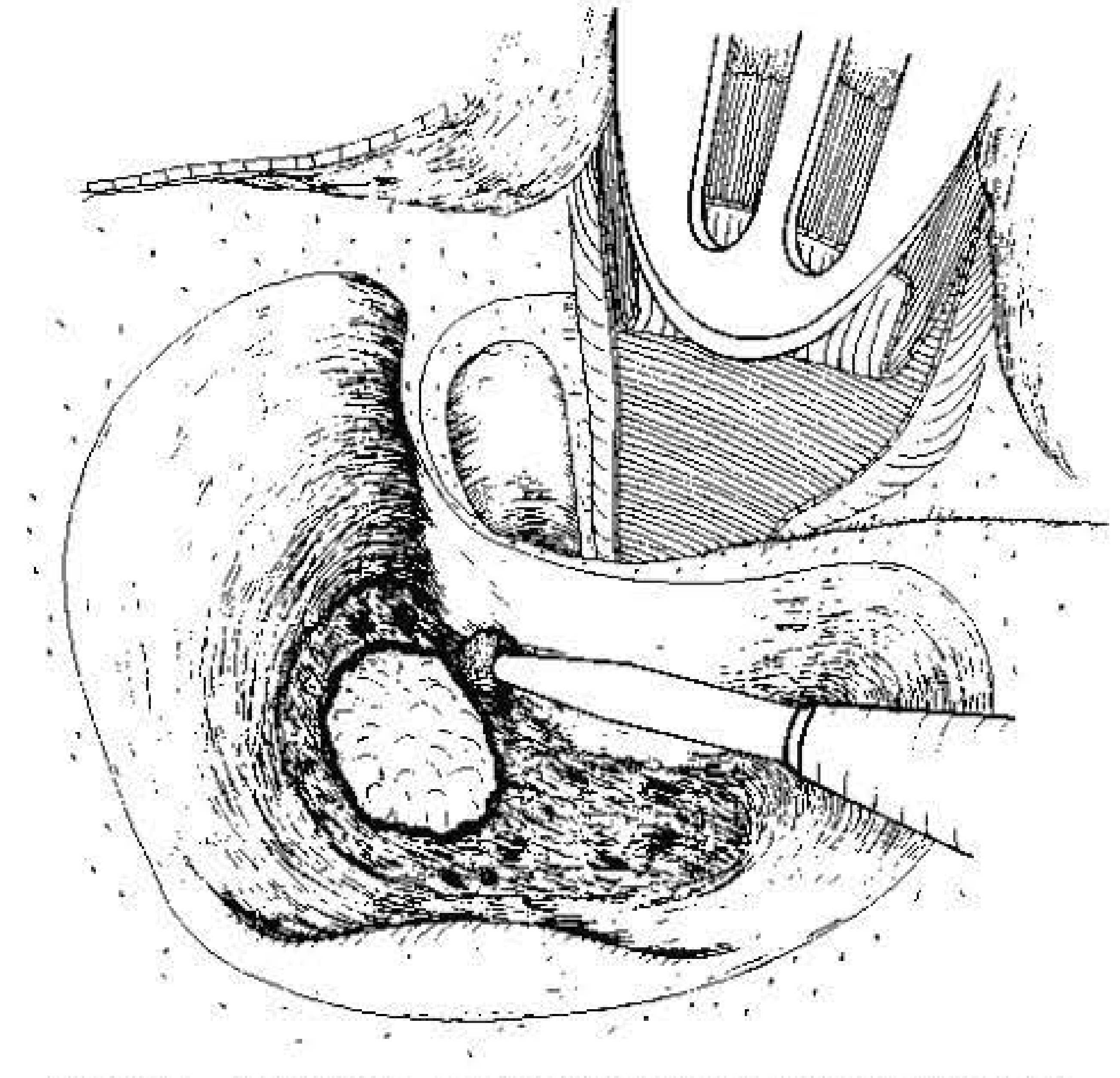


Fig. **424** **Modified intact canal wall mastoidectomy.** After the mastoid cells have been exenterated and Körner's septum penetrated, the cholesteatoma is exposed, and further bone around the cholesteatoma is removed

Removal of Large Attic Cholesteatoma

If the cholesteatoma extends into the antrum, and the superior border of the cholesteatoma membrane cannot be removed through the atticotomy opening, then this part is left in place, and is dissected after the intact canal wall mastoidectomy (Fig. **423**). After the mastoidectomy and thinning of the posterior ear canal wall have been carried out, and after the antrum has been exposed, the cholesteatoma becomes visible, and is removed using the same principles as described previously, i. e., gradual deroofing by drilling the bone away with a diamond burr and elevating the matrix from the bone (Fig. **424**). After the roof of the cholesteatoma in the antrum has been removed, the plane between the bone and the cholesteatoma membrane can be established (Fig. **425**), and the cholesteatoma sac can be elevated from all sides (Fig. **426**). After incision of the matrix, the debulking of the cholesteatoma is performed using a large suction tube and a rougine (Figs. **427, 428**). The debulked cholesteatoma can now be gradually dissected away from the bone. The cholesteatoma membrane is elevated from the lateral semicircular canal, with care being taken to note any underlying fistula. Elevation of the membrane from the lateral semicircular canal should be carried out in such a way that no sharp instruments are directed toward the semicircular canal, so as to avoid probing with an instrument into an unsuspected fistula (Fig. **429**). After dissection of the cholesteatoma from the medial edge of the bony ear canal wall (Fig. **430**), care should be taken to assess its extent medial to the incus body. Elevation of the membrane from the medial side of the incus can sometimes be carried out without any need for incus removal. The membrane has to be elevated gradually from all sides, first from the edge of the bony canal wall, then from the short process of the incus, in order to identify the proper cleavage plane (Fig. **431**). To get better access to the anterior attic, more bone from the mastoid tegmen and tegmen tympani must be drilled away (Fig. **432**). Access to the tympanic orifice of the Eustachian tube is widened by transmastoid atticotympanotomy, as described previously. Finally, the cholesteatoma membrane is elevated from the incus and malleus, maintaining them intact if possible (Fig. **433**). Dissection between the ossicles and the medial wall of the preserved bony ear canal wall is carefully undertaken (Fig. **434**) from all sides by gradually rolling the membrane under the bony ear canal toward the opening of the atticotomy

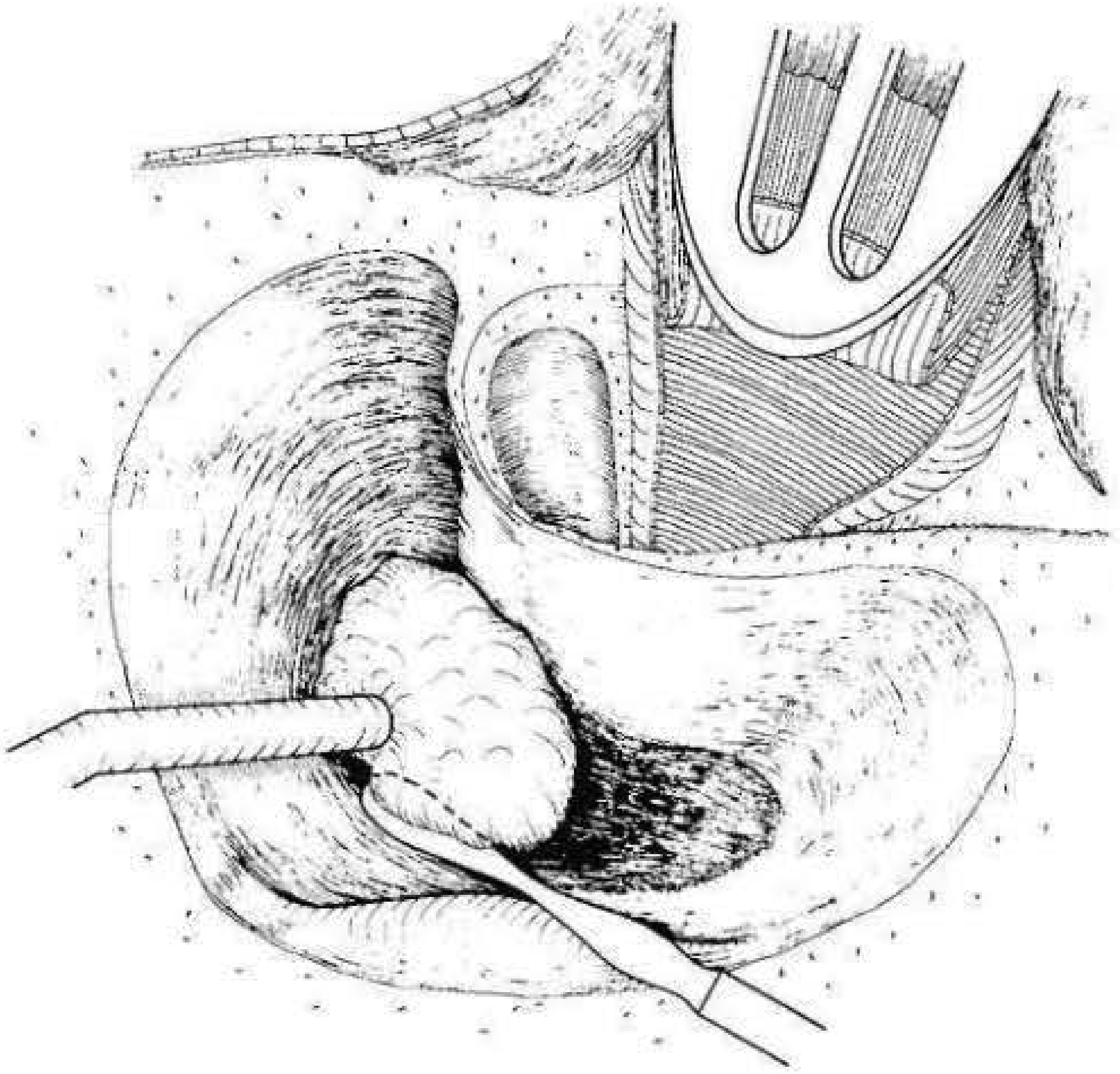


Fig. **425** The bone around the cholesteatoma is removed. The cholesteatoma sac is elevated from the bone

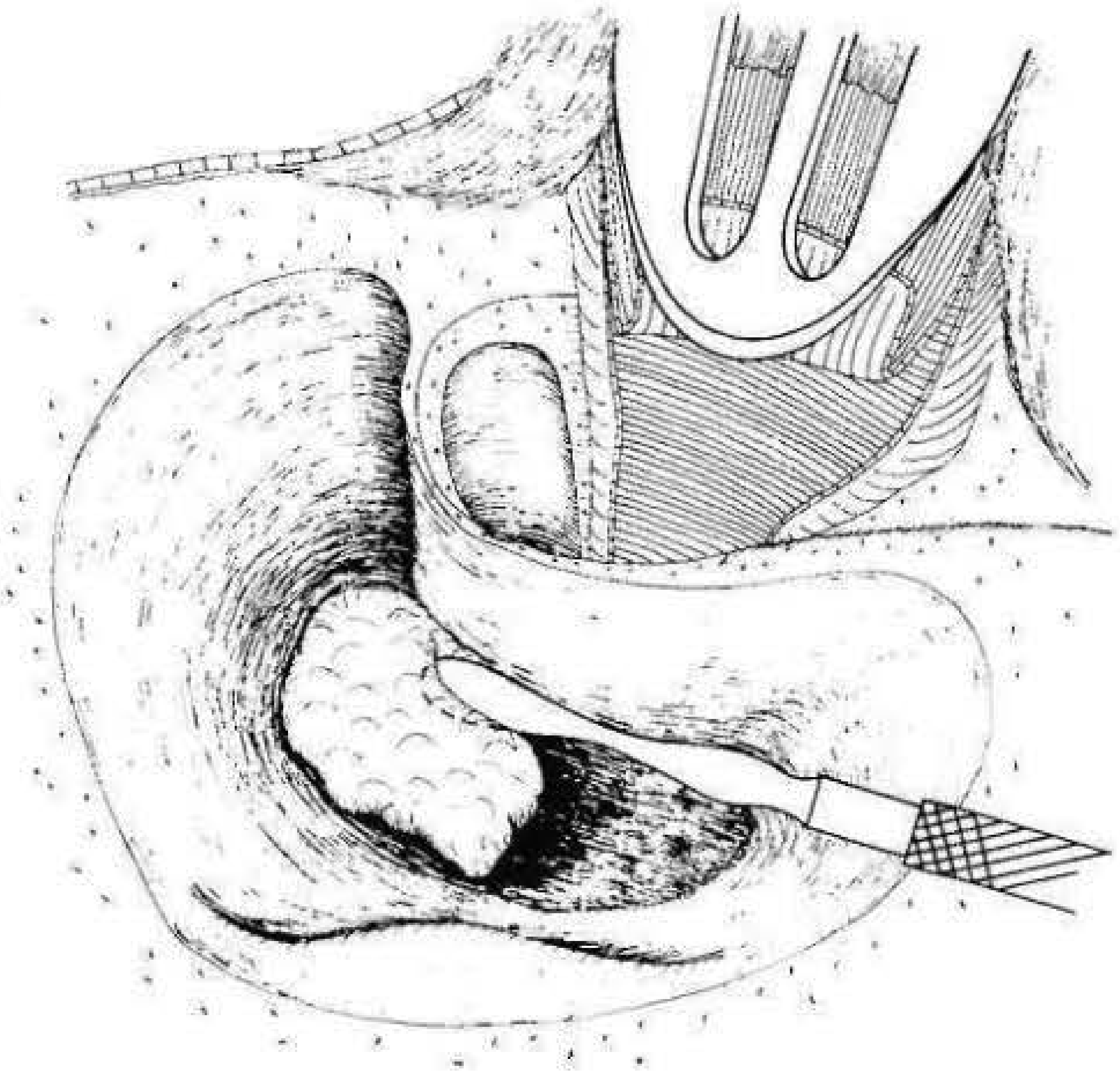


Fig. **426** Further elevation of the cholesteatoma sac anteriorly

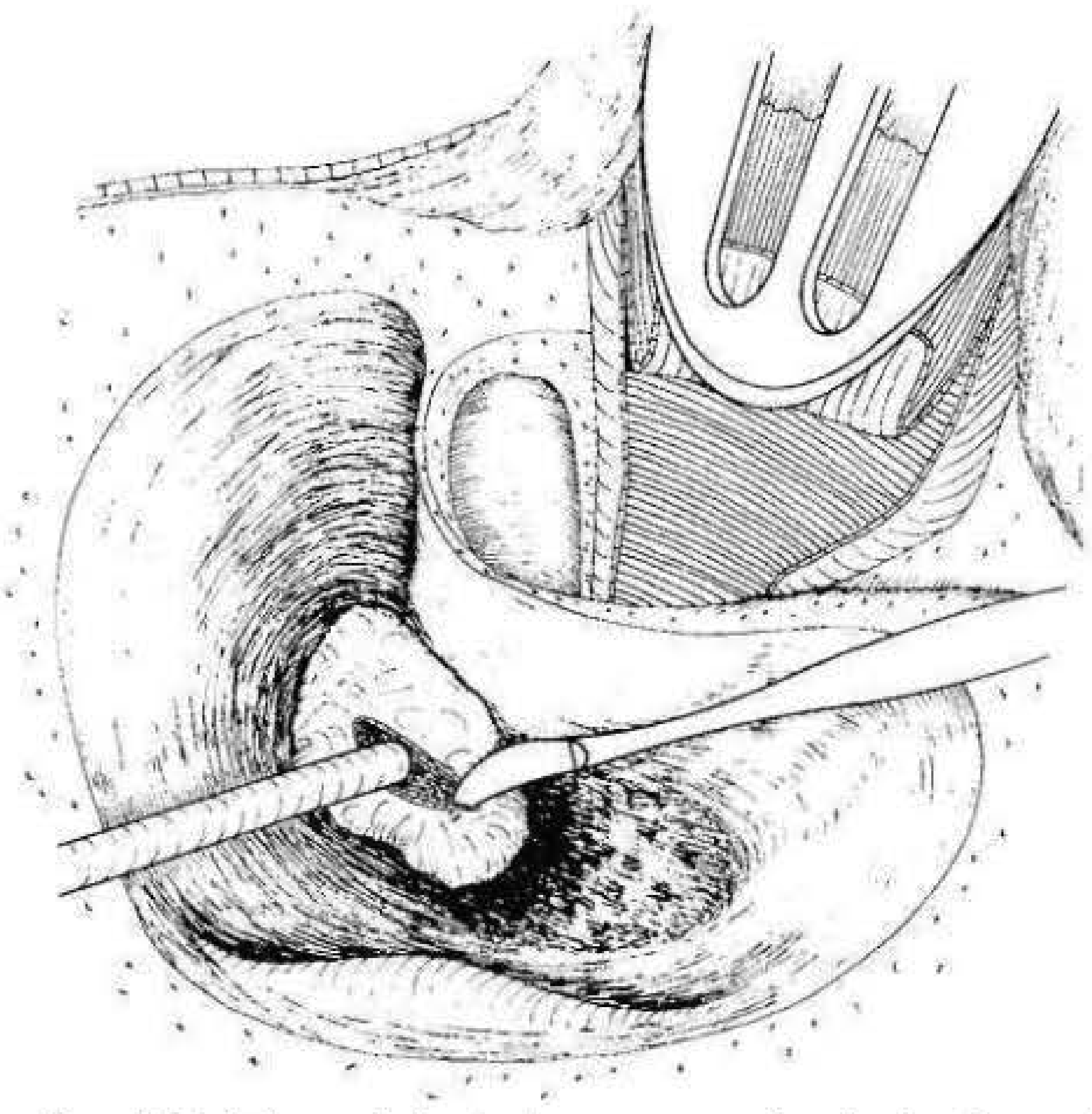


Fig. **427** The cholesteatoma sac is incised and debulked using a suction tube

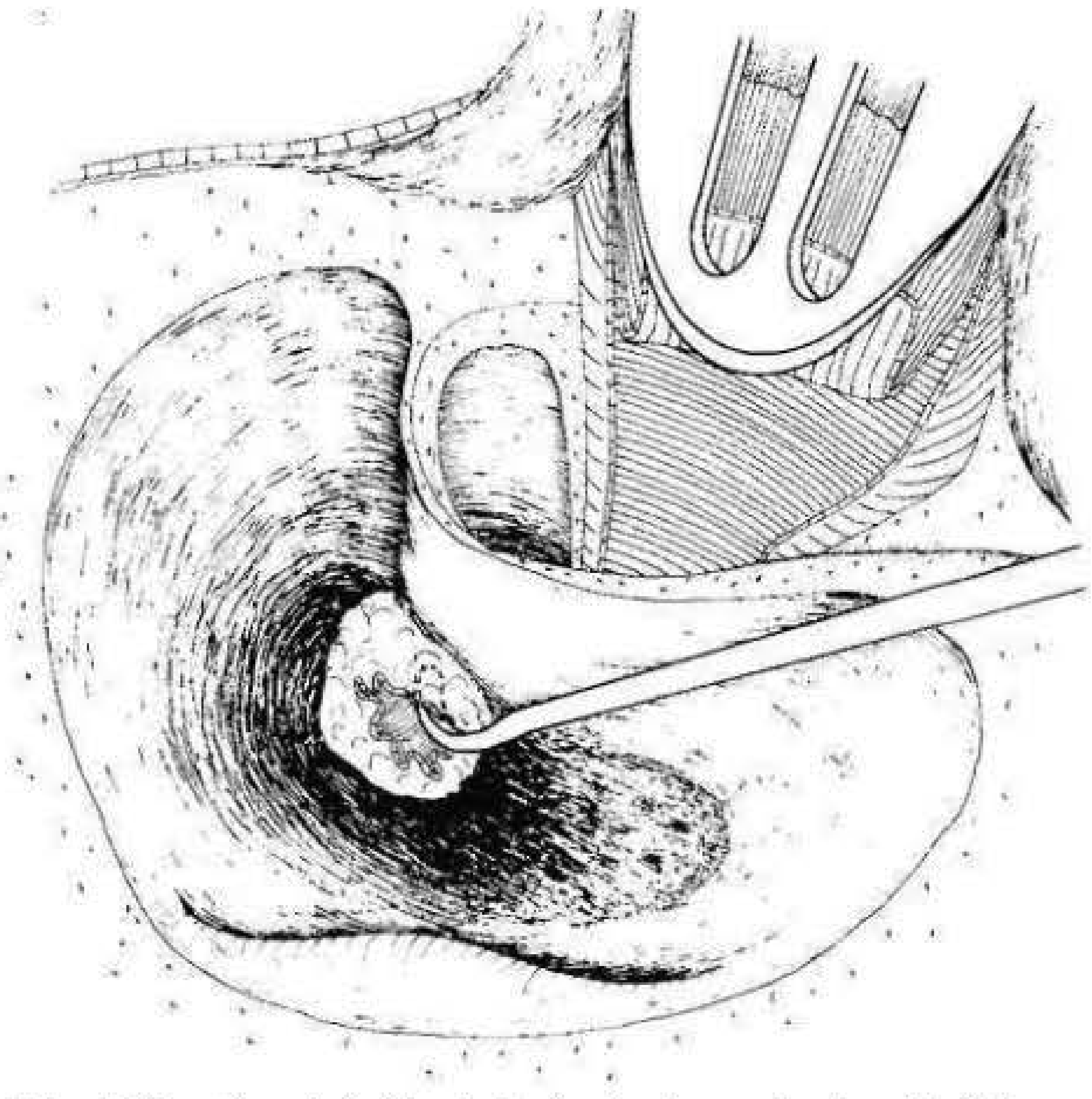


Fig. **428** The debulked cholesteatoma is elevated from the medial wall of the antrum, the prominence of the lateral semicircular canal is carefully palpated to exclude a labyrinthine fistula

(Fig. **435**), where the last part of the membrane can be removed by suction or by using curved forceps (Fig. **436**). After complete removal of the cholesteatoma, a final check for residual cholesteatoma is undertaken using a curved instrument, moving it along the inner edge of the posterior ear canal wall and the inner edge of the bridge (Fig. **437**). In addition the connection between the anterior attic and the tympanum is established and secured by removal of the tensor tympani fold and any other adhesions located in the inferior attic and by further removal of the bone, allowing entry into the epitympanic sinus and the supratubal recess, as indicated in Figures **419–422**.

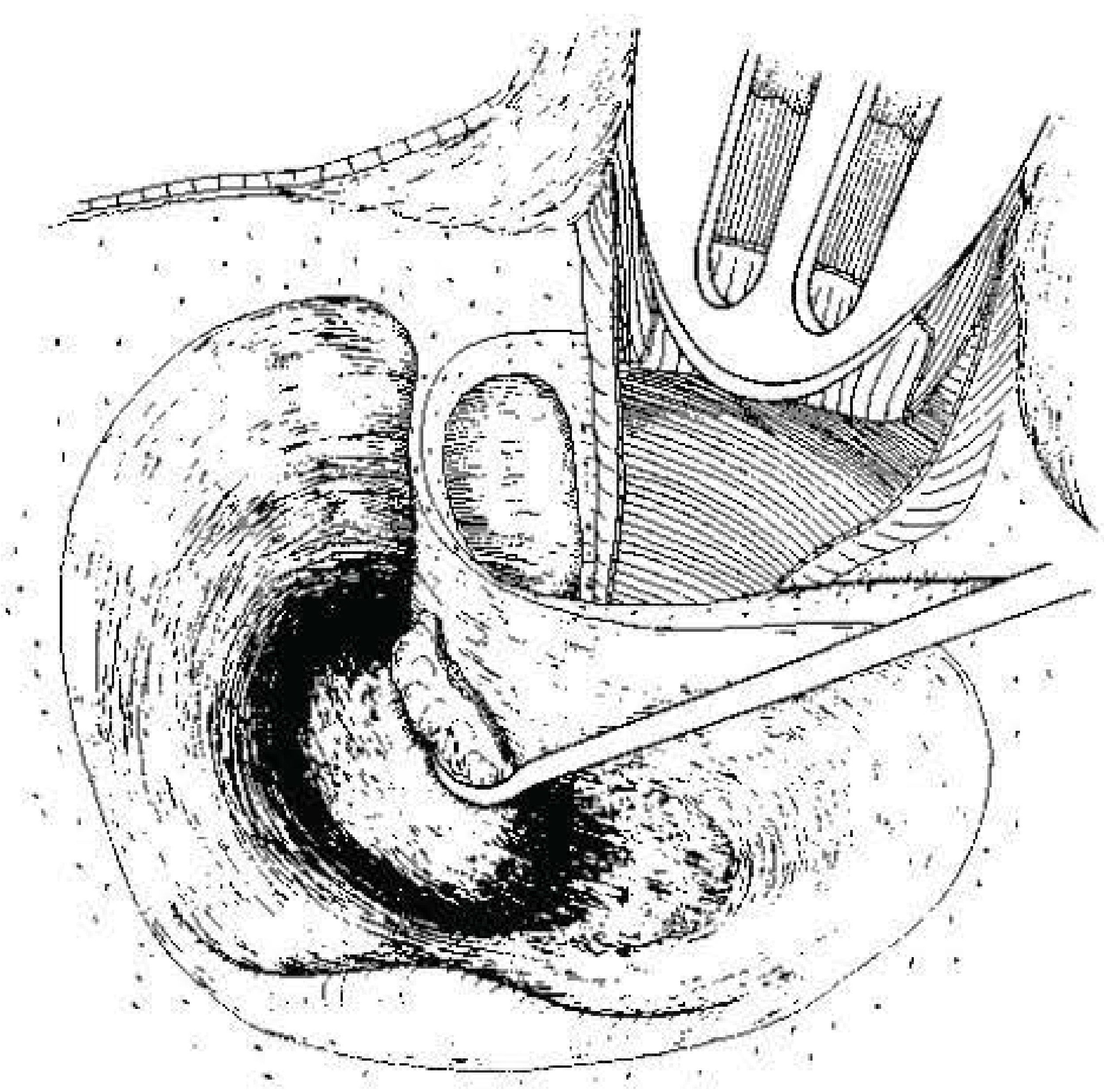


Fig. **429** The "medial" cholesteatoma membrane is elevated from the lateral aspect of the semicircular canal. With a curved rugine, the cholesteatoma membrane is dissected from the border of the ear canal

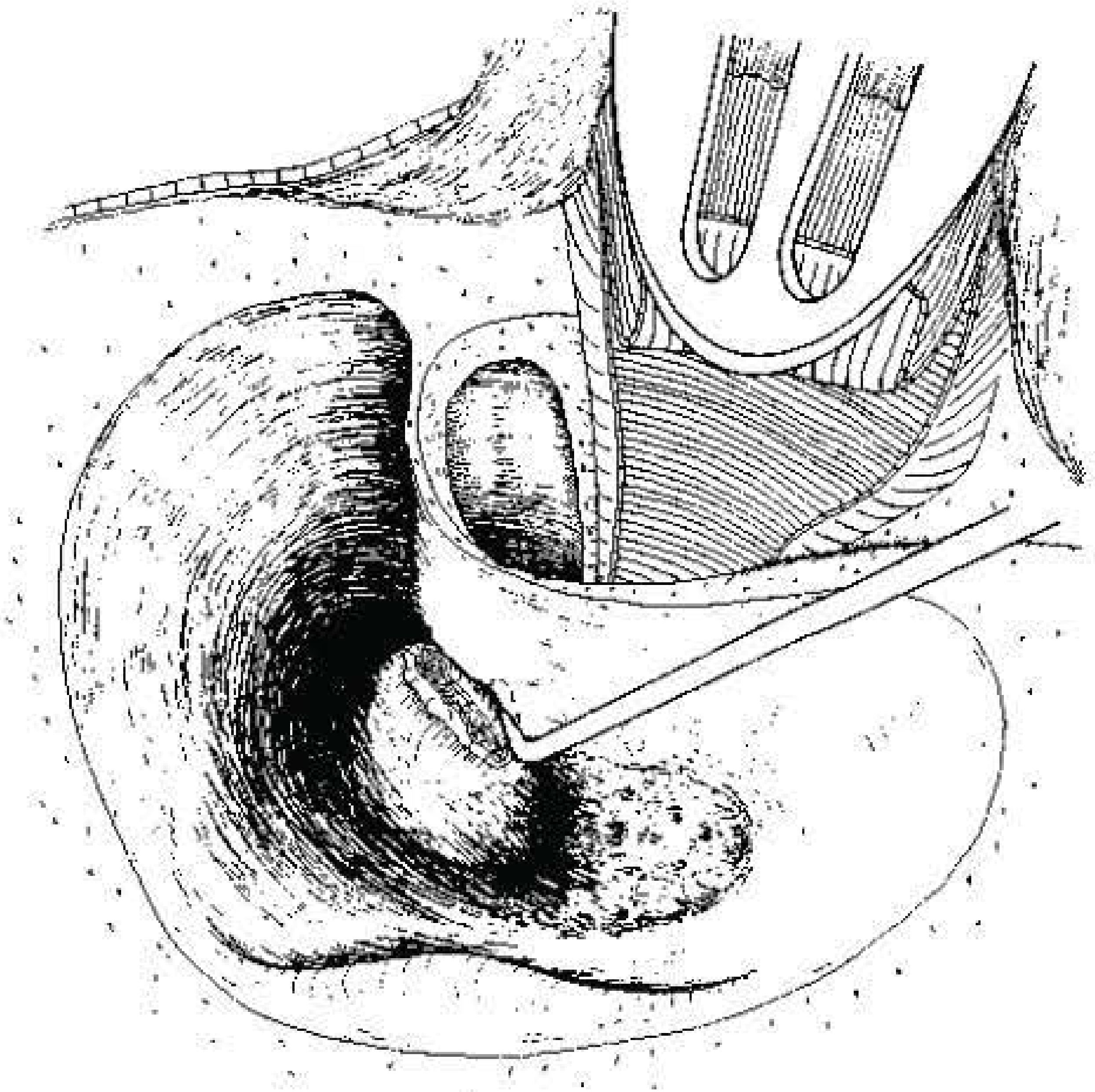


Fig. **430** A curved rugine is placed transmastoidally under the medial edge of the bony ear canal wall, and the "lateral" cholesteatoma membrane is elevated from it

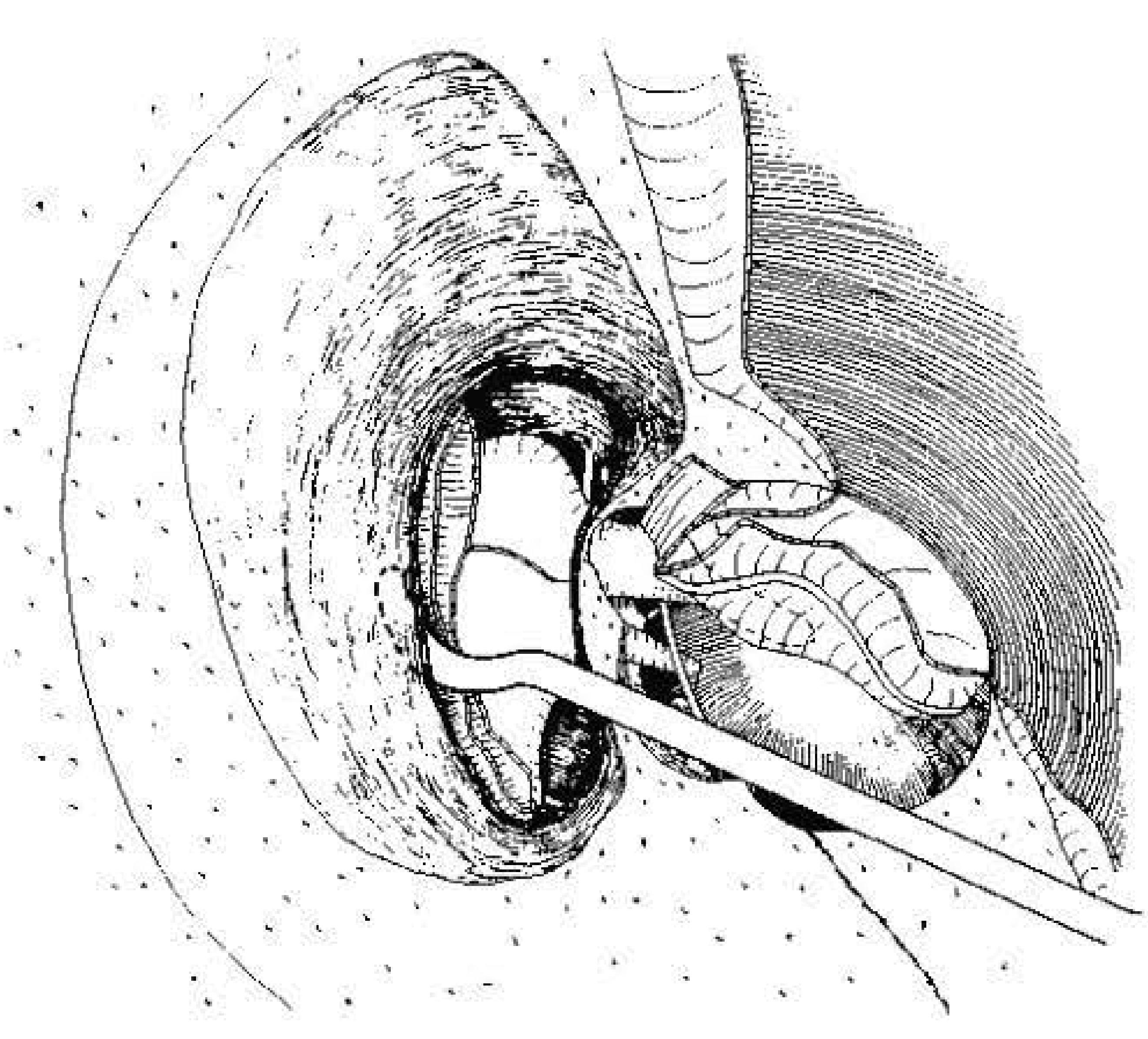


Fig. **431** A curved rugine is placed through the atticotomy, and the "lateral" cholesteatoma membrane is further elevated from the medial border of the intact bony ear canal wall

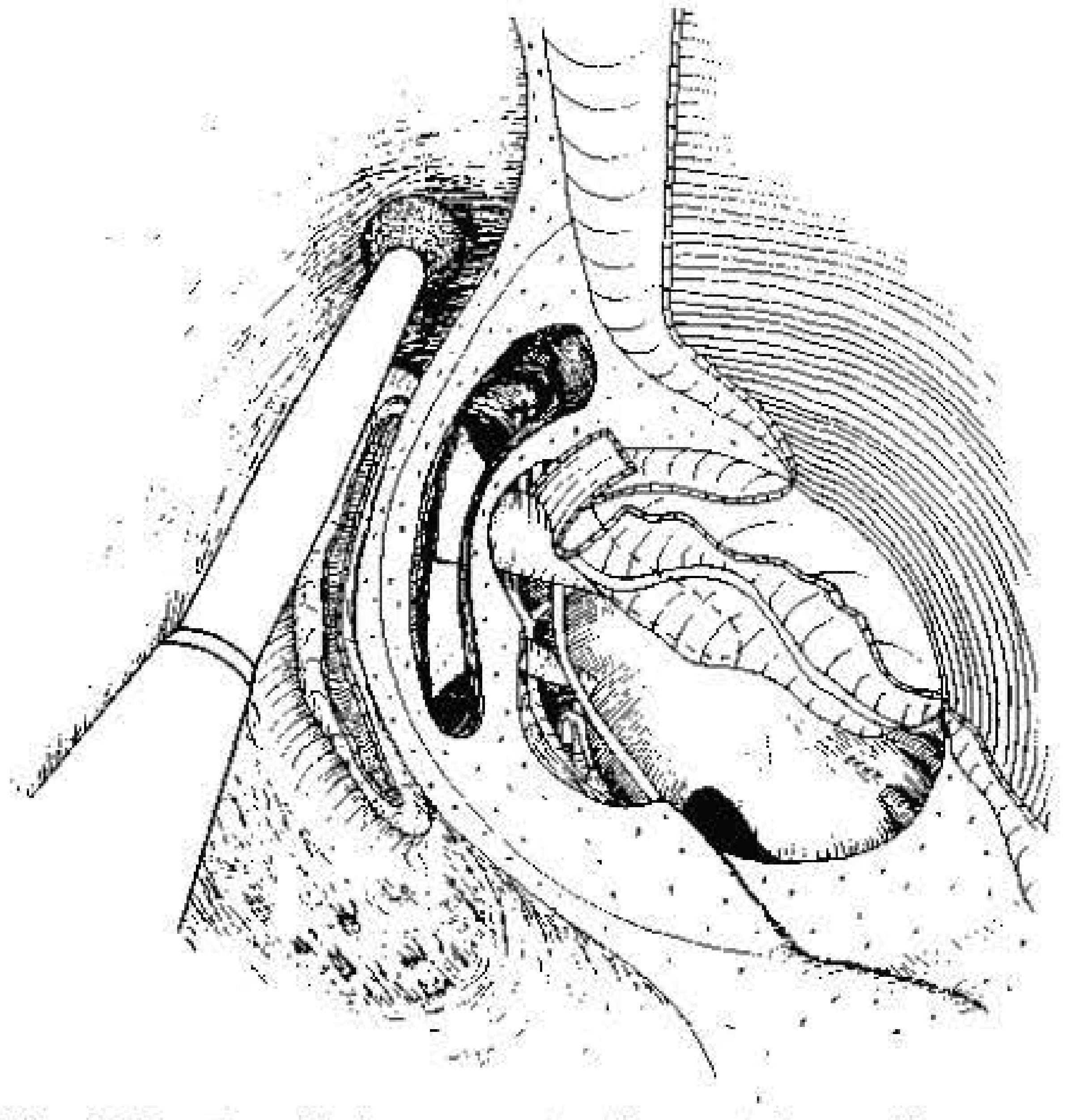


Fig. **432** To obtain acess to the anterior attic, more bone is drilled away from the mastoid tegmen

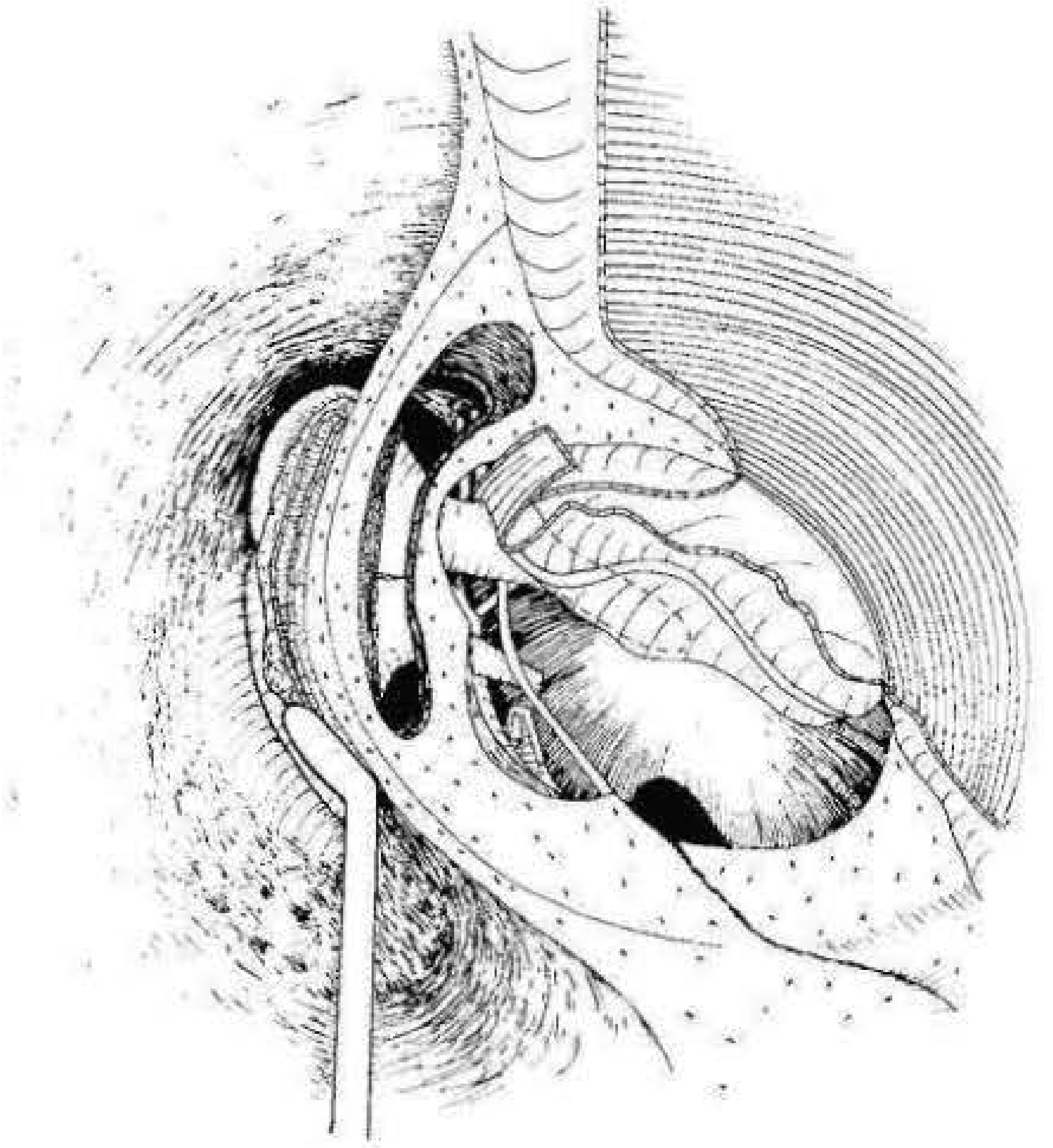


Fig. **433** The "medial" cholesteatoma membrane attached to the medial and superior aspects of the incus body is carefully elevated

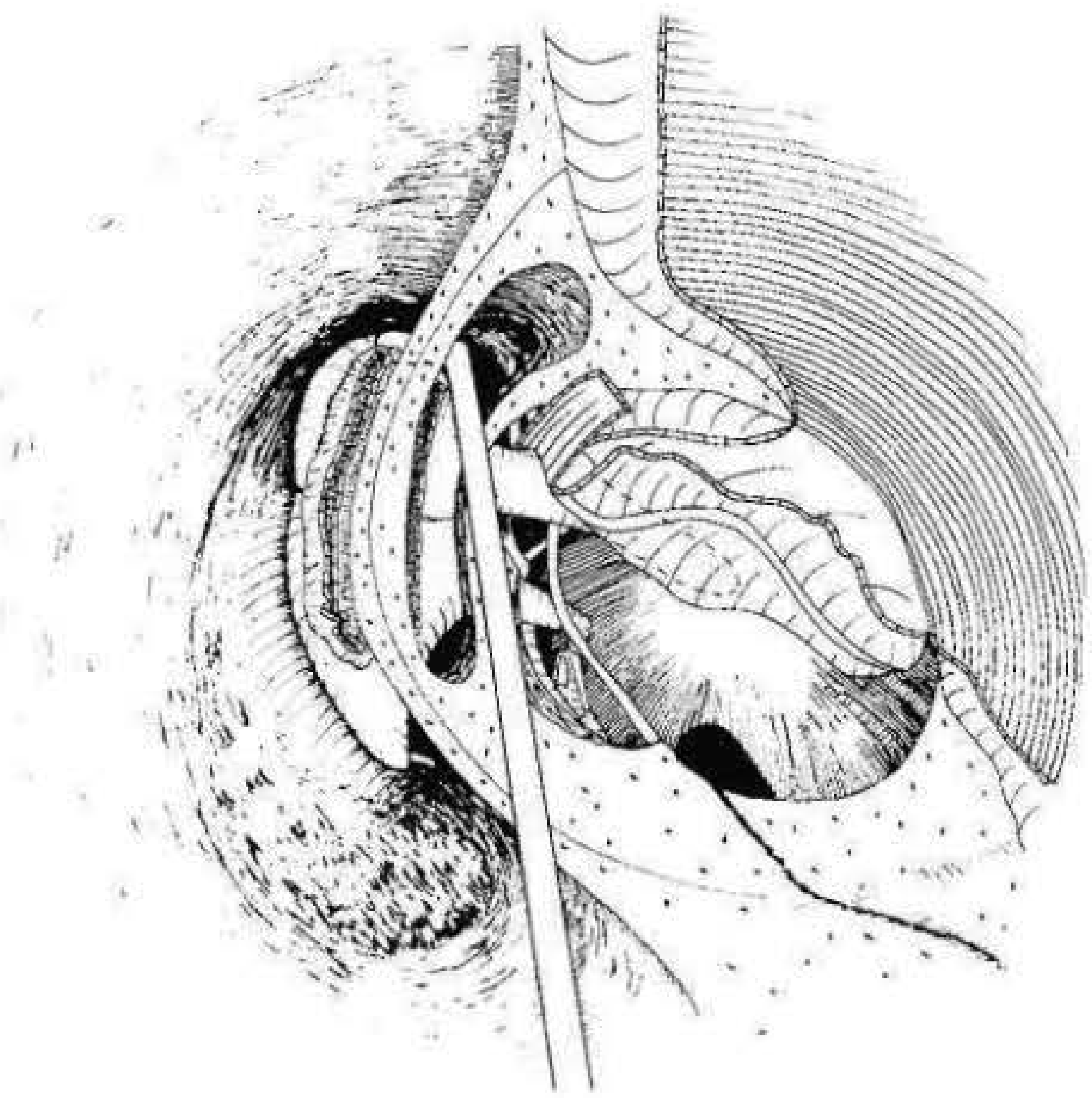


Fig. **434** The adherent cholesteatoma membrane is elevated from the lateral aspects of the incus body and malleus head

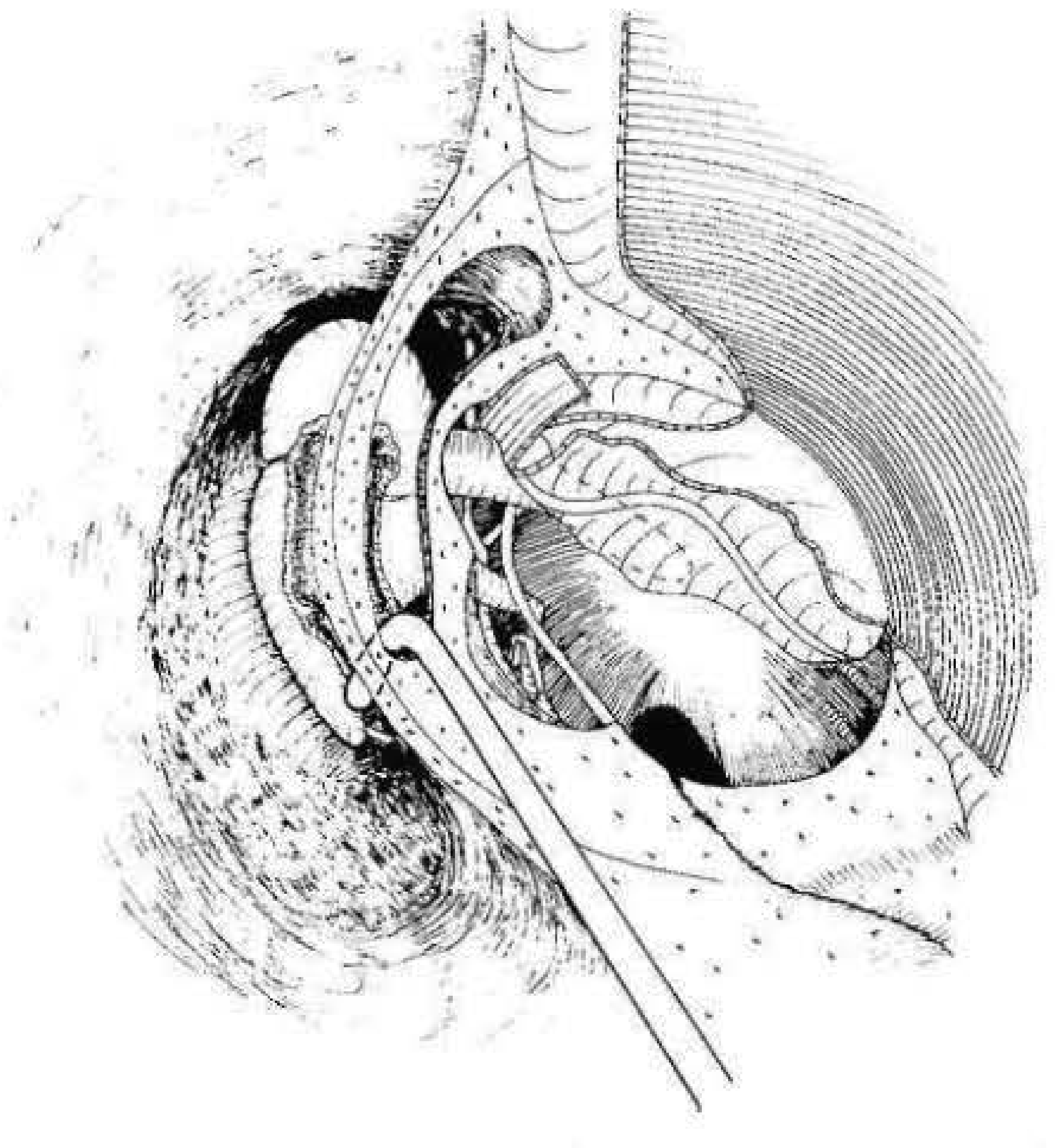


Fig. **435** The short process of the incus is cleaned of cholesteatoma membrane through the atticotomy, and is inspected through the transmastoidal route

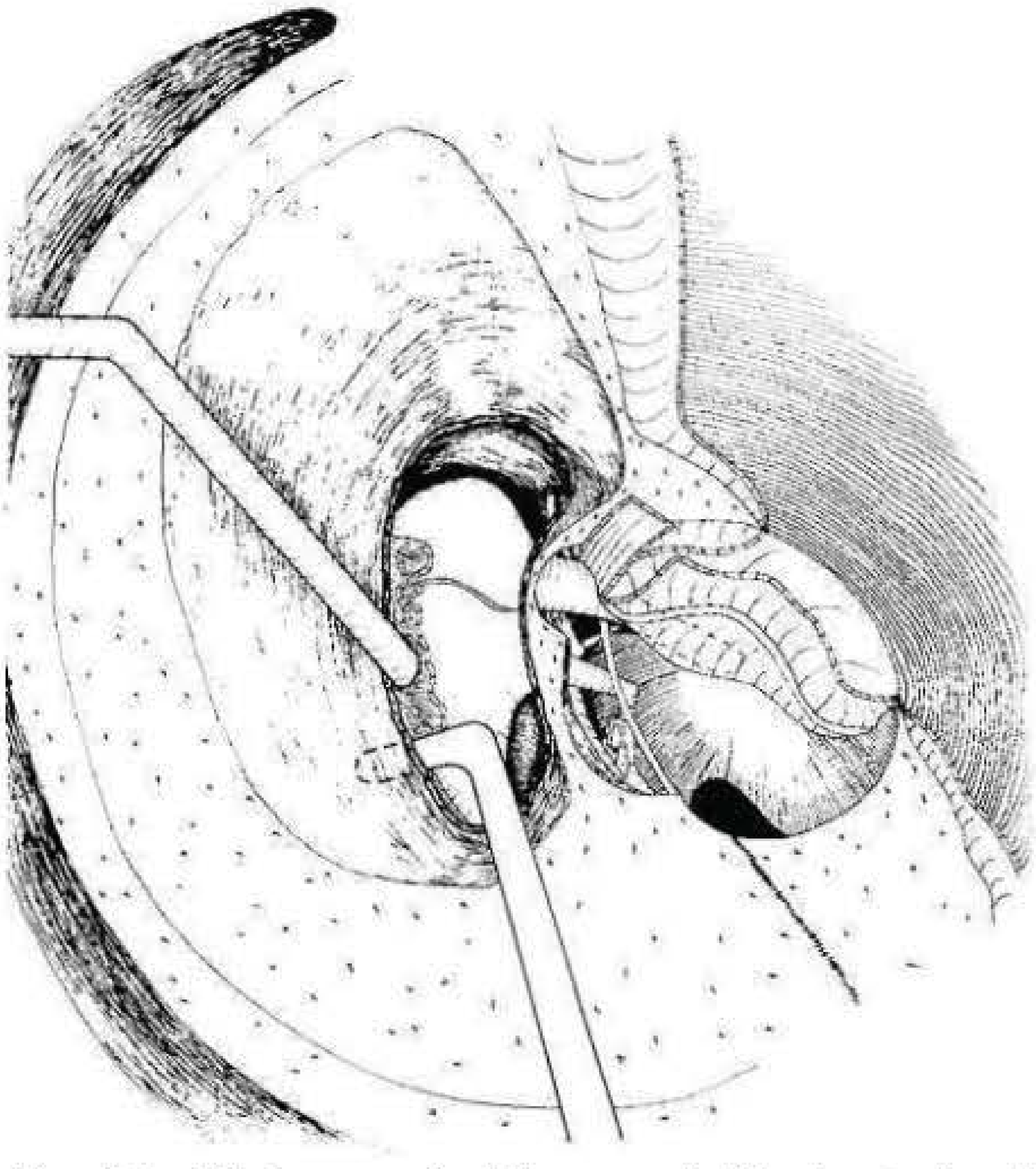


Fig. **436** Final removal of the completely elevated and freed cholesteatoma membrane by pushing it out of the attic with a curved rugine and pulling it with a strong suction tube

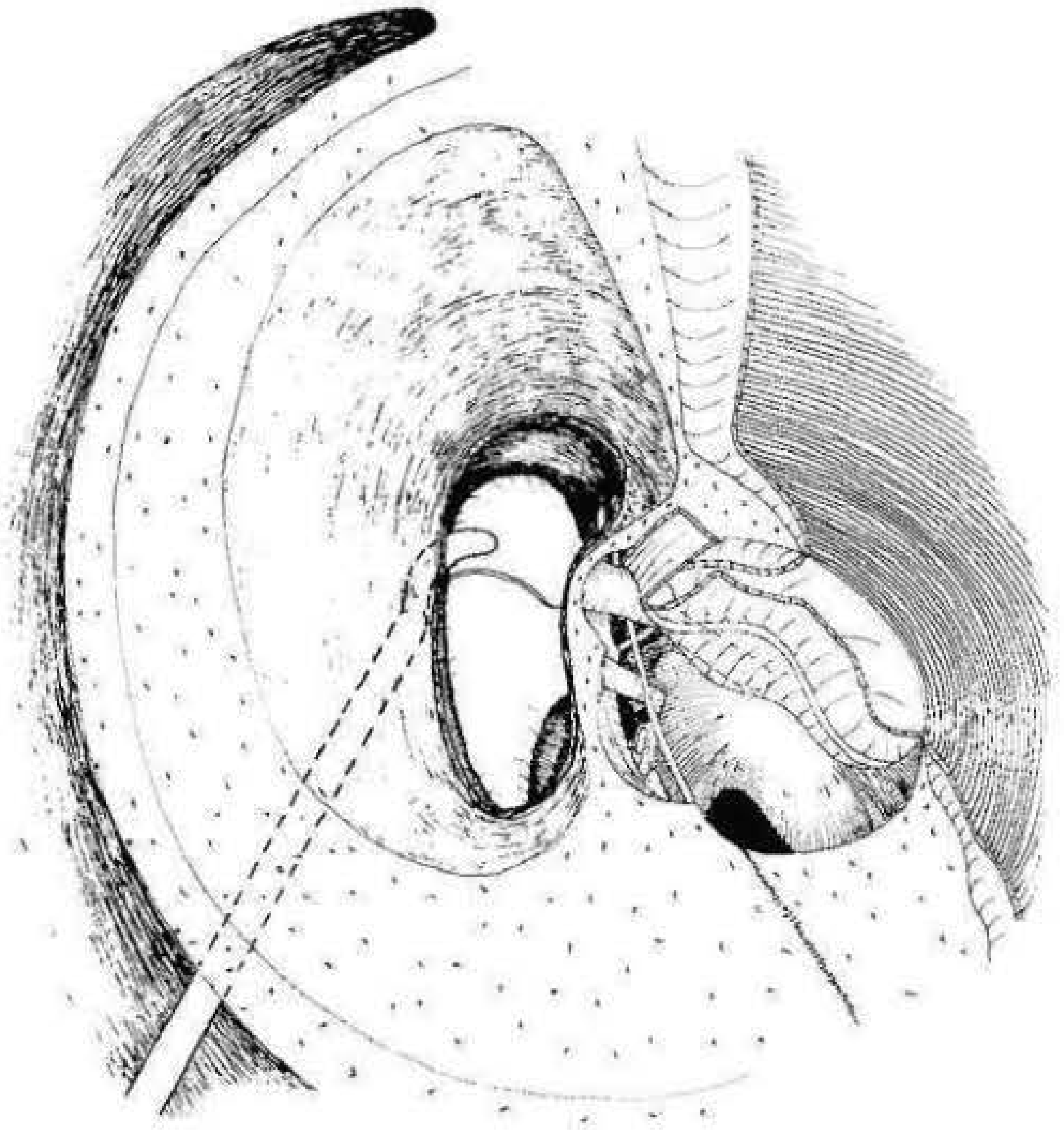


Fig. **437** Further checking and cleaning of the medial edge of the intact bony ear canal wall with a curved rugine

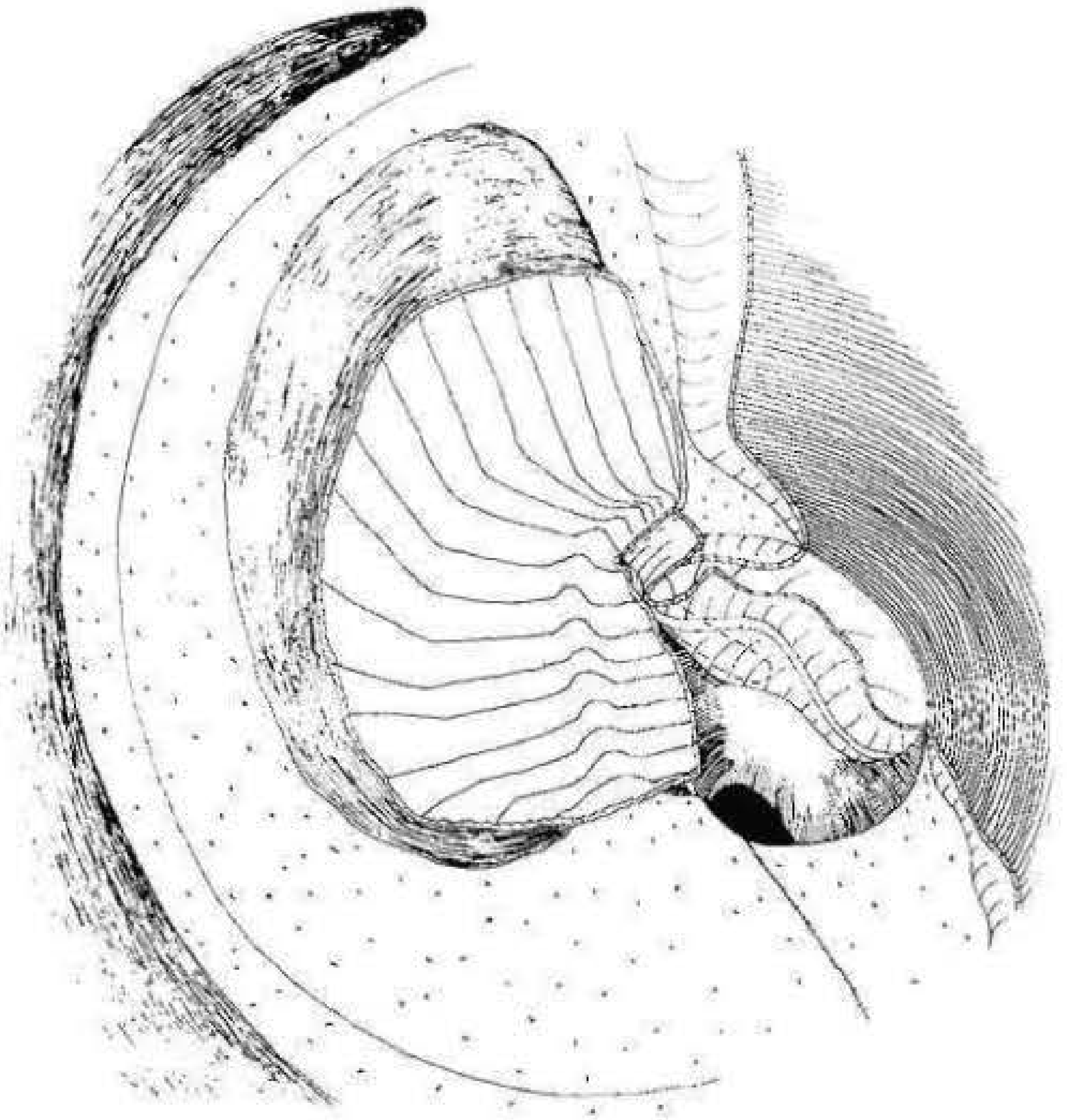


Fig. **438** **Covering the atticotomy with fascia.** The fascia is stretched over the atticotomy, and has no contact with the underlying ossicles. It is placed over the bridge, but under the drum

Reconstruction of Atticotomy with an Intact Chain

Covering the atticotomy opening in cases with an intact ossicular chain and intact bridge is relatively easy, because retraction does not usually occur in the atticotomy region. Even if retraction does occur, the membrane will attach to the incus body and malleus head, and usually does not extend any further posteriorly. The atticotomy opening can be covered by autogenous fascia grafts (Figs. **438, 439**), tragal or conchal cartilage, or a piece of autogenous cortical bone (Fig. **440**). Covering the atticotomy opening is really not a problem in cases with an intact, normally positioned bridge. Especially useful in such cases are small pieces of bone acquired by chiseling of the mastoid process, since the shape of these pieces often fits exactly into the atticotomy opening.

When using conchal cartilage, which is slightly concave in shape, a piece can be adapted to the shape of the atticotomy opening and the bridge. First, a piece of silastic can be cut to the appropriate size and shape, and then a piece of cartilage of exactly the same shape as the silastic can be cut and placed onto the attic defect (Fig. **440**).

Since covering the attic with bone or cartilage makes it impossible to see into the attic after the operation, the author prefers, particularly in cases with an intact chain and intact bridge, to cover the atticotomy opening with fascia in order to be able to see into the attic and exclude residual cholesteatoma, avoiding the need for a second-look operation.

Care is taken to place the fascia onto the denuded neck of the malleus (Fig. **439a**) and anteriorly between the bridge and the drum (Fig. **438**). The fascia should not cover the malleus head or the incus body, and there should be some space between the ossicles and the fascia. The small malleus flap and the other ear canal skin flaps are replaced, and the ear canal is packed with Gelfoam balls and small pieces of gauze moistened with oxytetracycline hydrochloride and hydrocortisone ointment (Terra-Cortril). Finally, a thick tube is placed through a separate hole behind the incision and into the cavity for ventilation (Fig. **441**).

Generally, there is only a minor risk of retraction in cases with an intact ossicular chain and intact bridge, and if retraction occurs, it starts between the neck of the malleus and the bony bridge, i. e., at exactly the same place as the attic retraction that caused the original attic cholesteatoma (Fig. **442**). If the atticotomy opening is only covered with fascia, retraction may occur at the atticotomy, but will adhere to the malleus head (Fig. **442 a**) and seldom

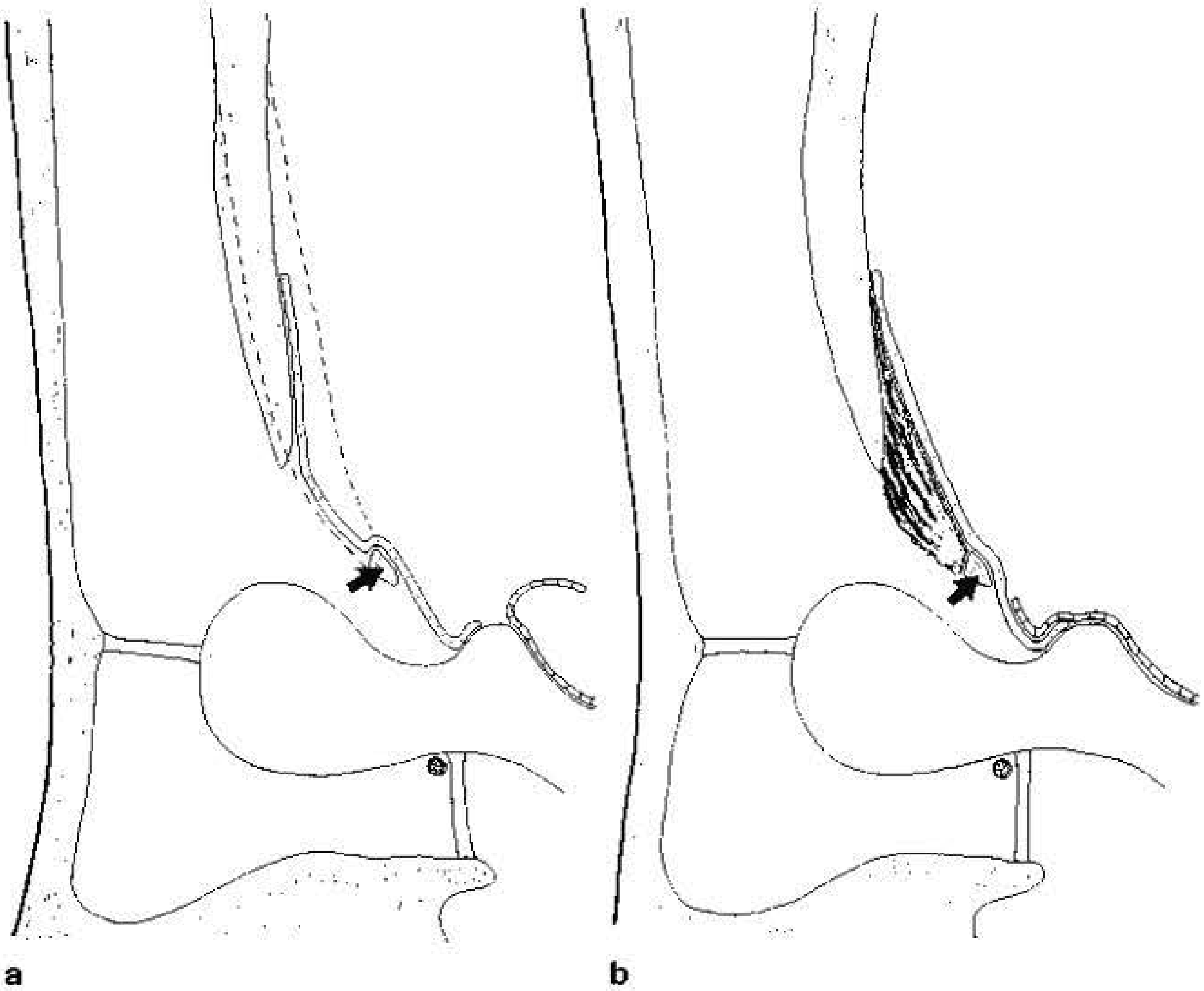


Fig. **439** Side view of the modified intact canal wall mastoidectomy with atticotomy, intact ossiculuar chain, and preserved bony bridge (arrow).
a Atticotomy covered with fascia only. Fascia covers the attic region and the short process of the malleus, but it has no contact with the ossicles.
b Atticotomy covered with a bony shell harvested by chiseling of the matoid surface

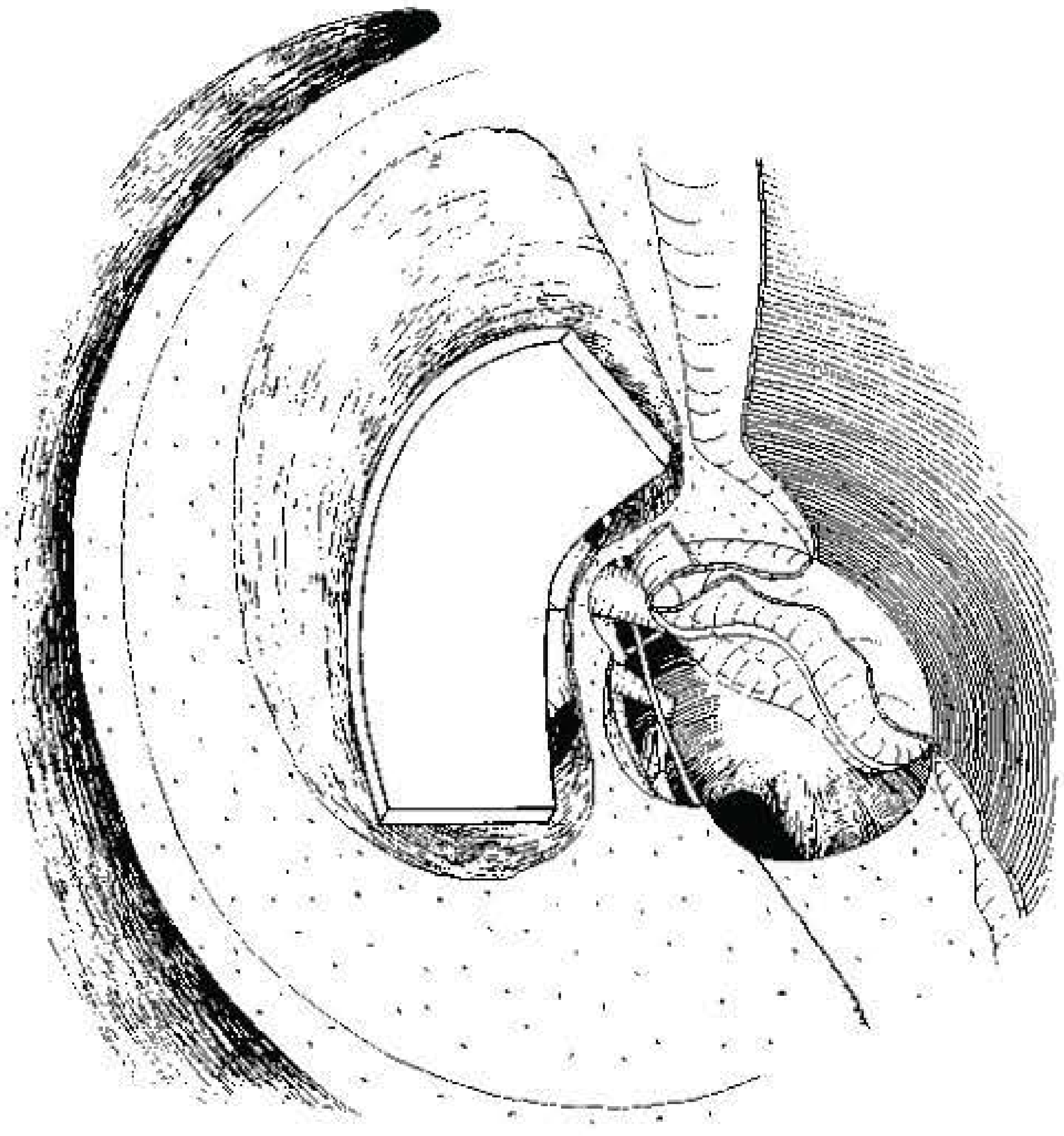


Fig. **440** **Covering the atticotomy with a conchal or sliced tragal cartilage**

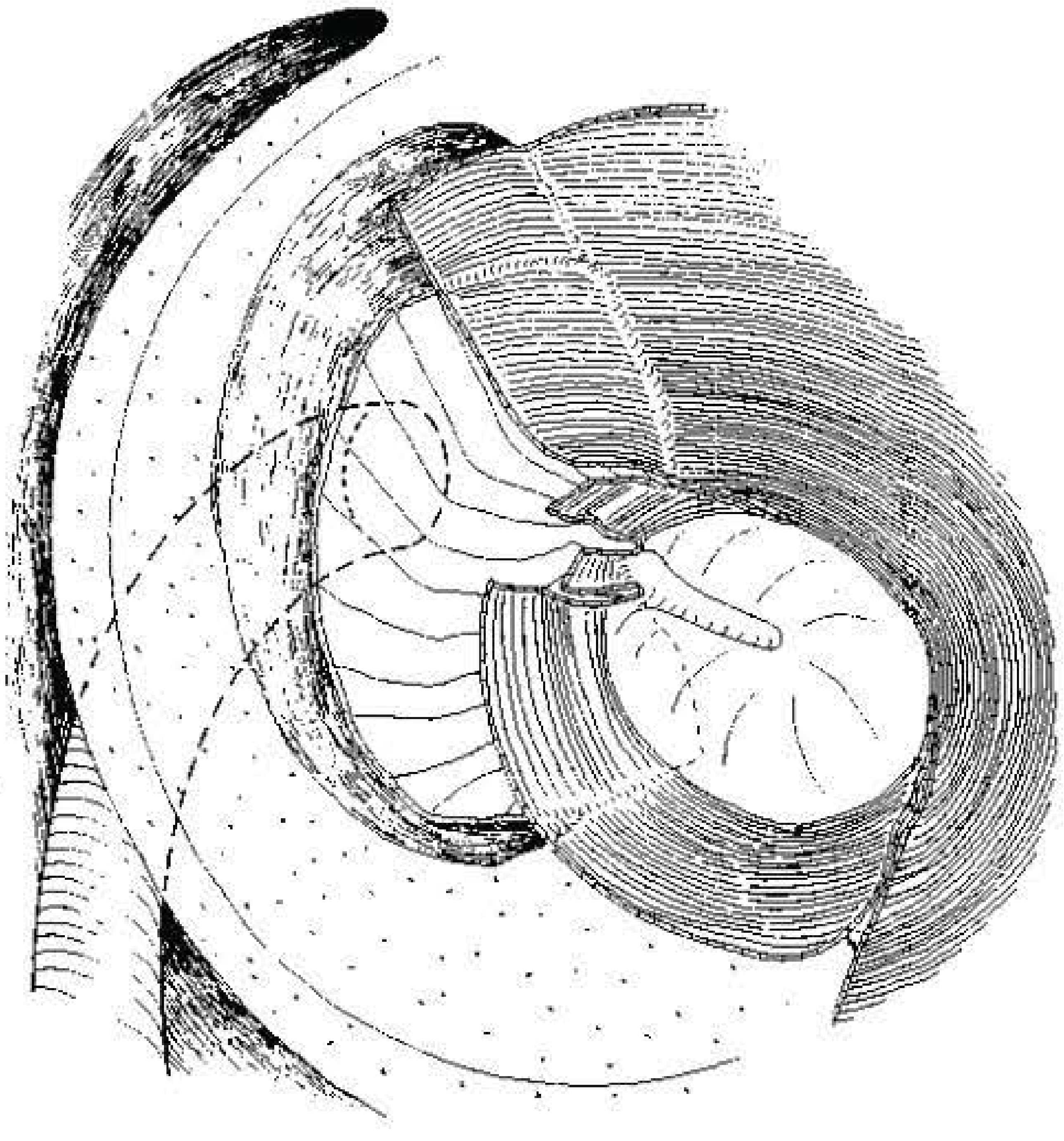


Fig. **441** **Ventilation of the mastoid cavity.** The epithelium flaps are replaced, and the mastoid cavity is ventilated through a thick ventilation tube inserted into the mastoid cavity through a separate incision progress. The bridge and part of the medial edge of the ear canal may be resorbed and the retraction may extend with a large and safe neck (Fig. **443 a**). If the atticotomy opening is covered with bone (Fig. **439b**), the retraction may become deep (Fig. **442b**), extending behind the reconstructed ear canal wall (Fig. **443b**).

If there is mucus in the middle ear, which is not uncommon in cases of attic cholesteatoma, or thick mucosa with poor tubal function shown by a negative preoperative Valsalva maneuver, then a grommet is inserted anterosuperiorly in the pars tensa.

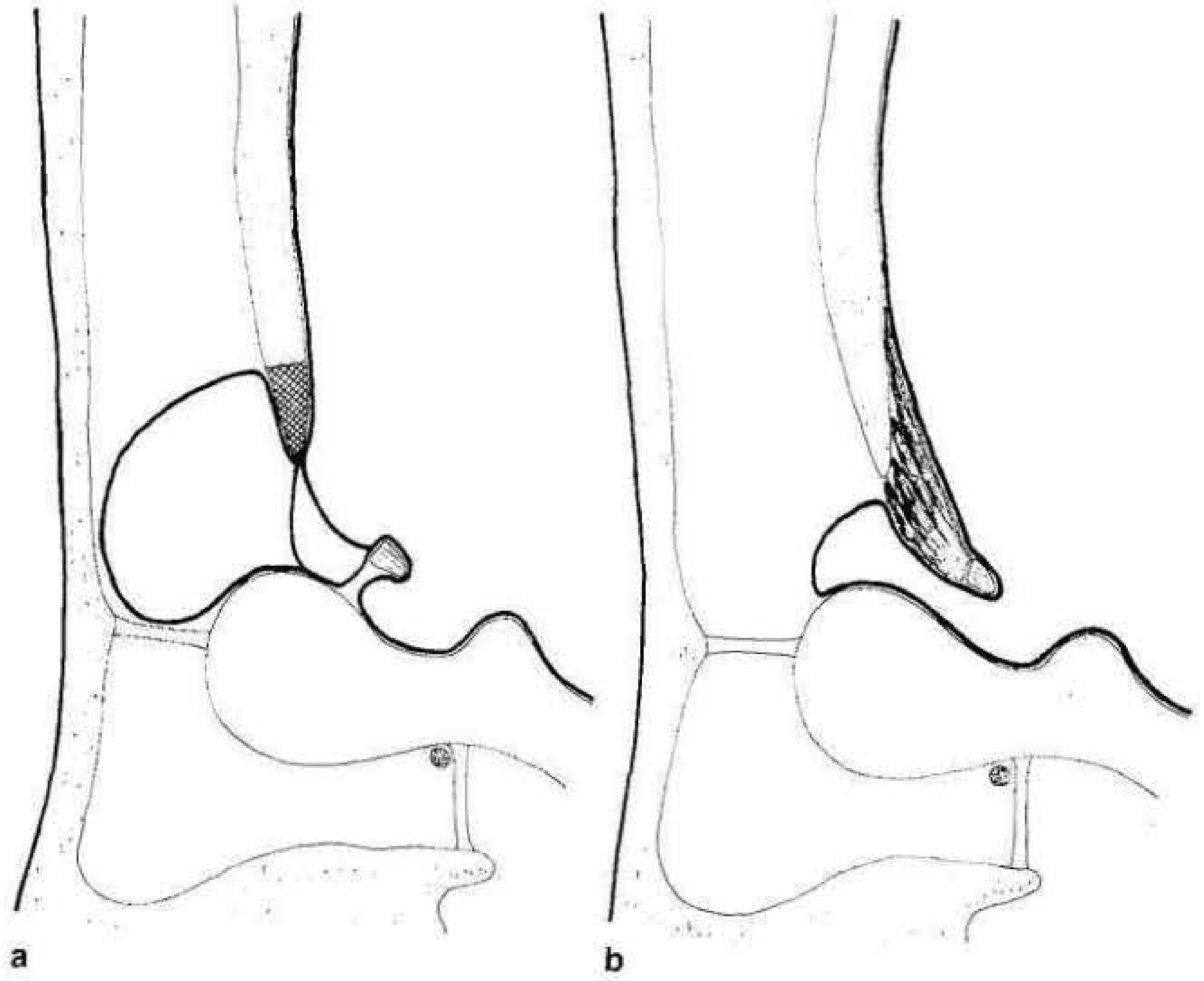


Fig. **442** **Postoperative retractions. a** Atticotomy covered with fascia only. A retraction onto the neck of the malleus, inferior to the bridge, cannot progress. Retraction superior to the bridge will attach to the head of the malleus, but can progress to a large retraction after resorption of the medial edge of the bony ear canal wall (shaded). **b** Retraction when the atticotomy is covered with bone. Retraction inferior to the bridge can progress and become unsafe.

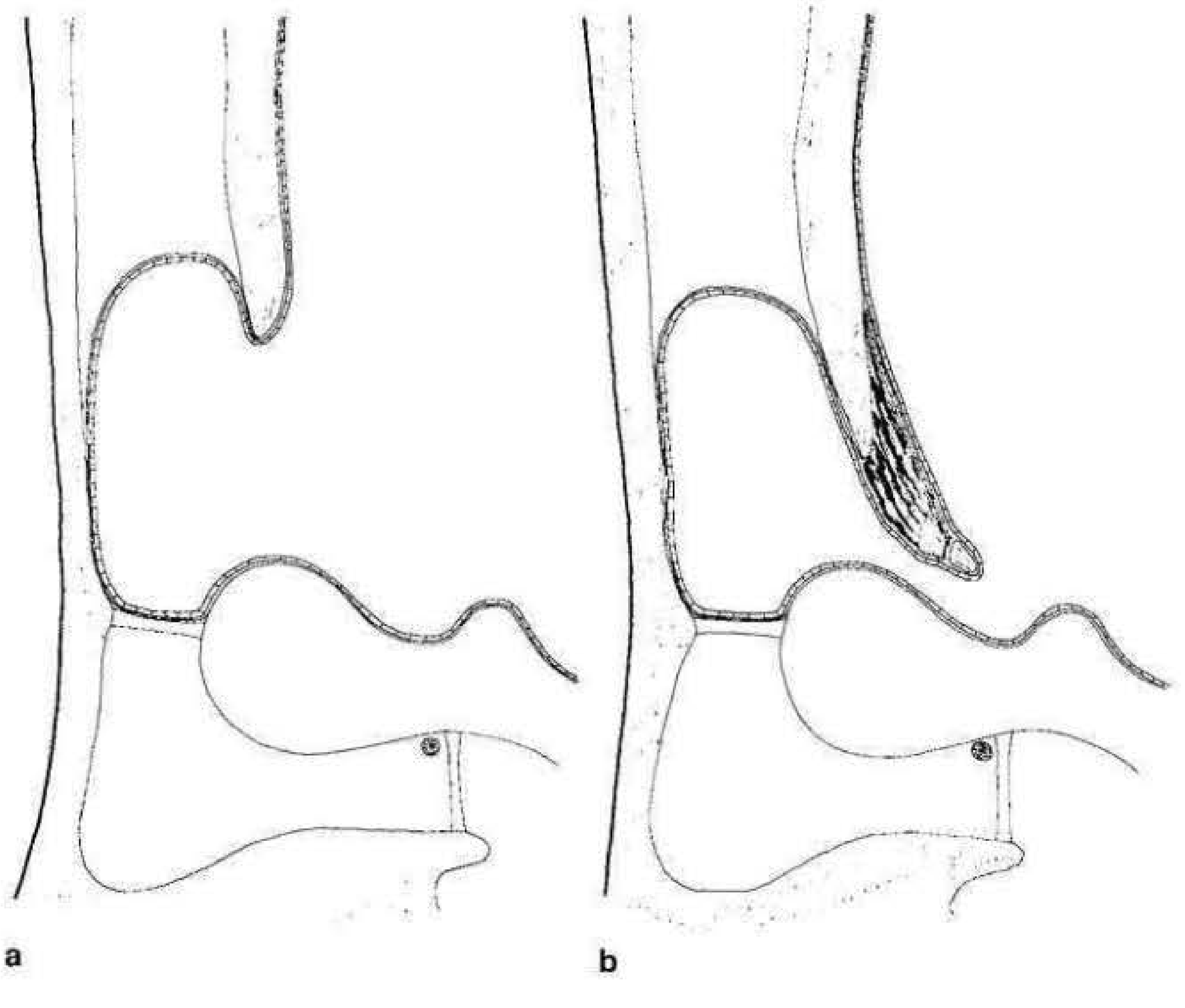


Fig. **443** **Outcome of the retractions. a** After being covered with fascia, the bridge and medial edge of the bony ear canal are resorbed, and a large, safe retraction, with wide access, may result. **b** When they are covered with bone, the retraction may proceed and become unsafe, possibly even progressing to retraction cholesteatoma

Attic Colesteatoma with Defective Ossicular Chain

After the incision as described previously (Figs. **387**, **388**), a posterior tympanotomy and otosclerosis drilling are performed. The tympanic sinus and the tympanic cavity are cleared of pathology, and a small malleus flap is then elevated, exposing the neck and carefully identifying the borders of the attic cholesteatoma (Figs. **390, 391, 444**). An atticotomy is performed (Figs. **391–396**), the cholesteatoma membrane is incised, the cholesteatoma is debulked, and its matrix is elevated (Fig. **445**). After removal of the cholesteatoma membrane from the incus, dissection continues toward the malleus handle, with careful cleaning of the membrane under the bridge (Fig. **446**). The defective incus is removed, providing a good view of the posterior attic and the lateral semicircular canal (Fig. **447**). Finally, the cholesteatoma membrane is removed from the anterior attic and the head of the malleus (Figs. **448, 449**). The head of the malleus, if not eroded, is left in place if the cholesteatoma has been totally removed.

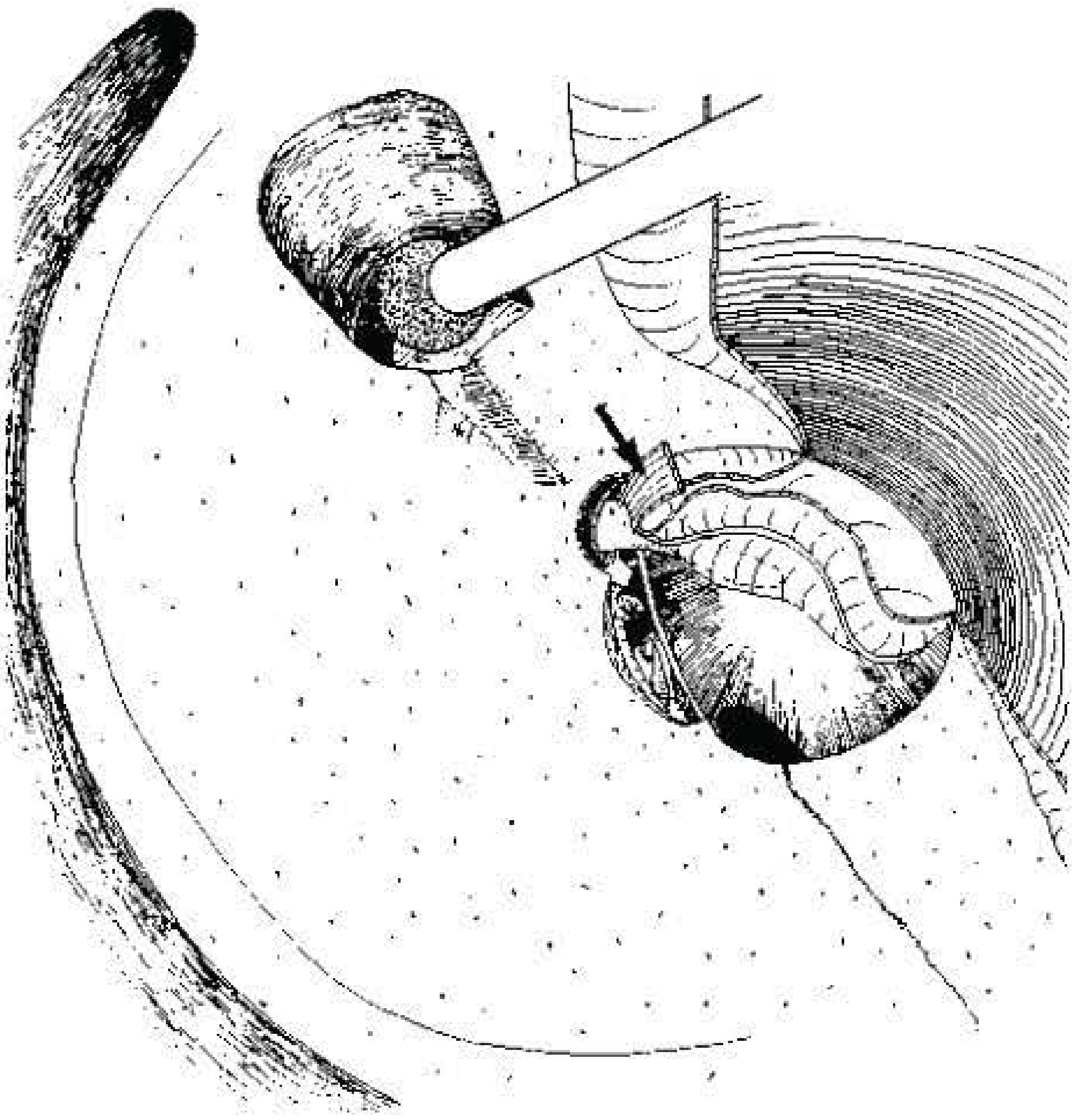


Fig. **444** **Removal of attic cholesteatoma with disrupted ossicular chain.** After a posterior tympanotomy, otosclerosis drilling, elevation of a small malleus flap (arrow), and cleaning of the malleus neck, the atticotomy drilling is initiated. The long process of the incus is defective, indicating a fast and safe atticotomy

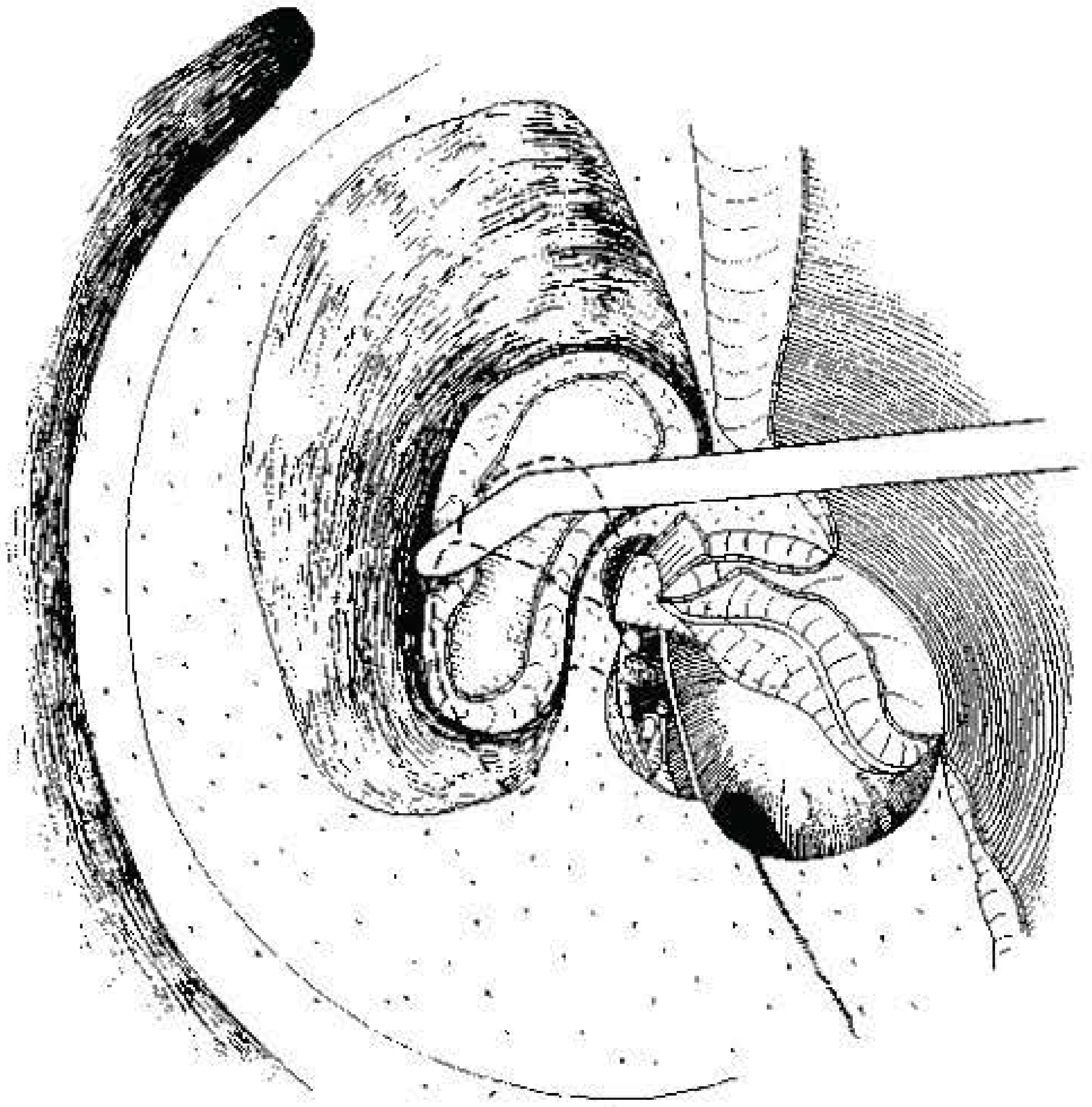


Fig. **445** The atticotomy is performed, the cholesteatoma membrane is elevated, and the cholesteatoma is debulked

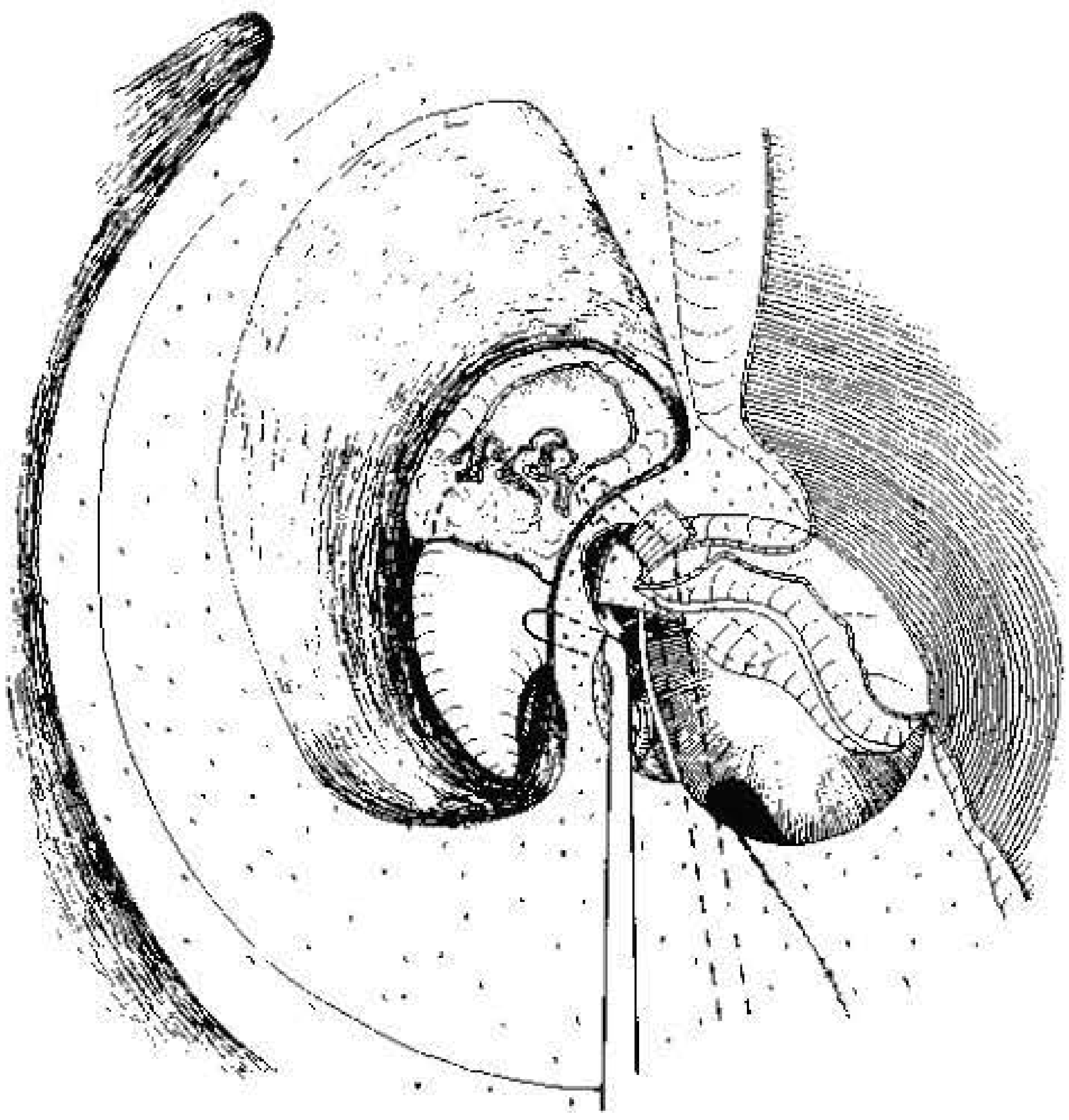


Fig. **446** The cholesteatoma membrane is removed from the incus, and the undersurface of the bridge is cleaned. The dashed instrument indicates the movement required to elevate the membrane from the bridge

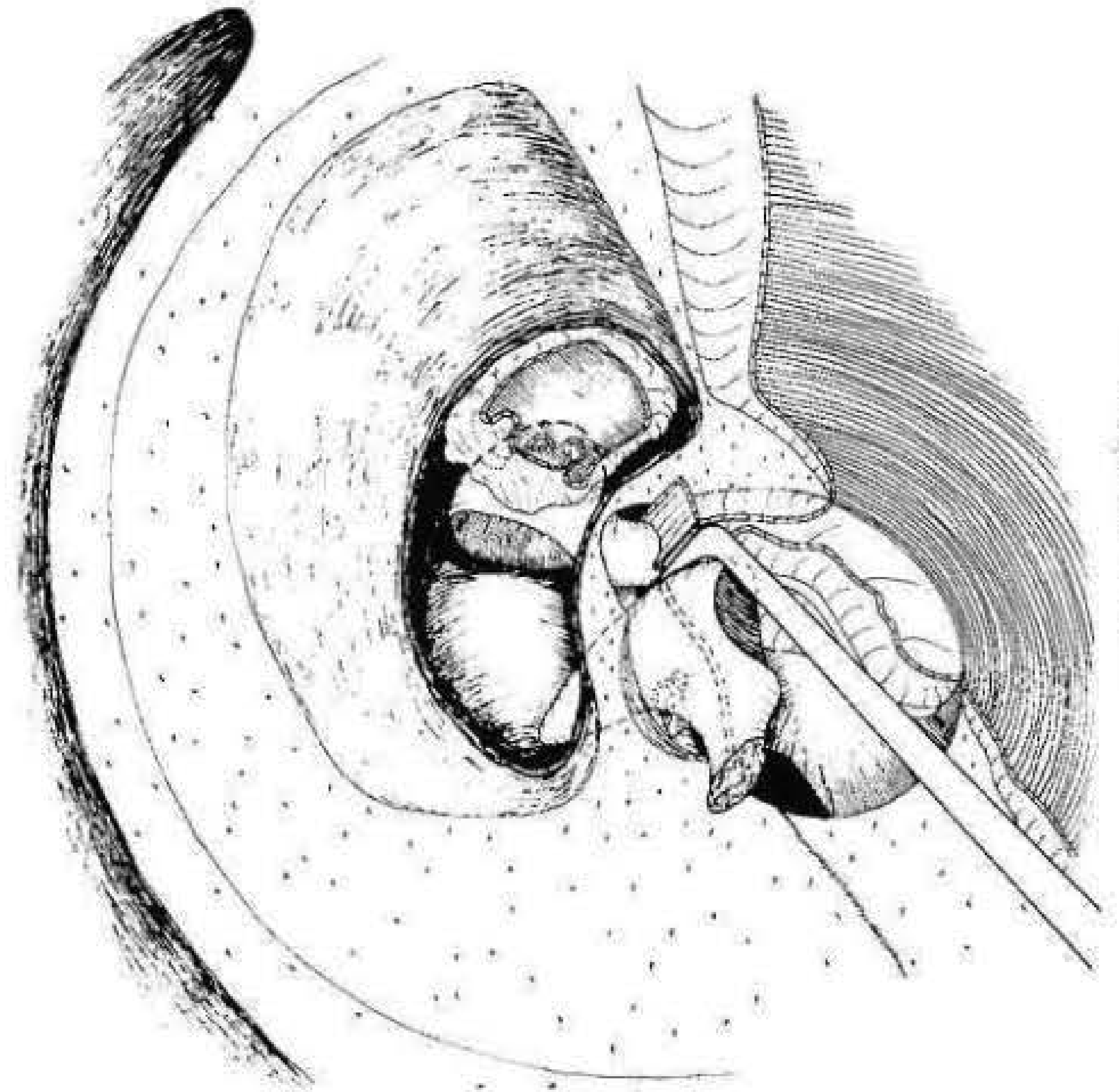


Fig. **447** The incus, is extruded and the cholesteatoma is cleaned from the neck of the malleus and the bridge

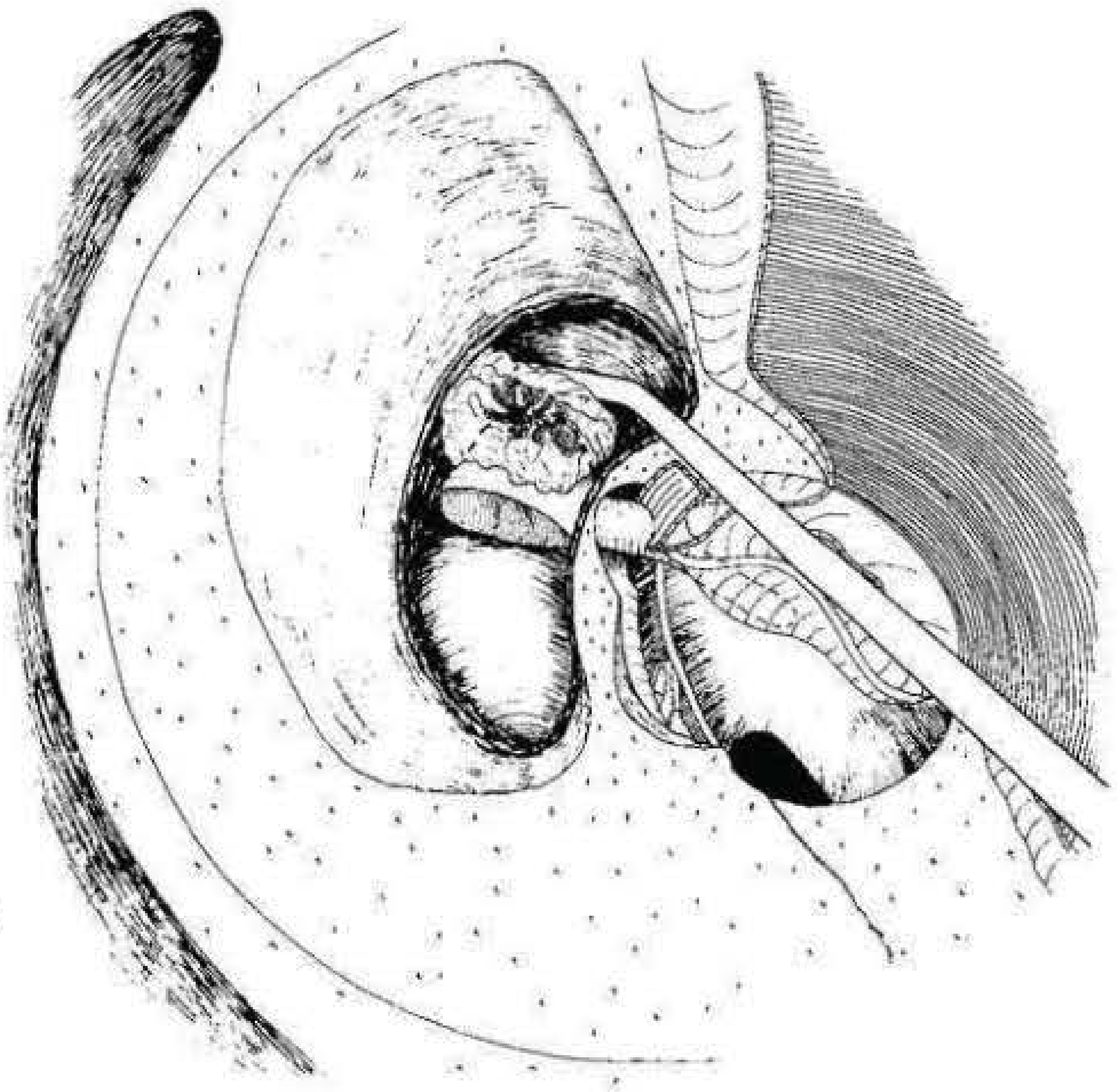


Fig. **448** The **cholesteatoma from the anterior attic is** carefully removed

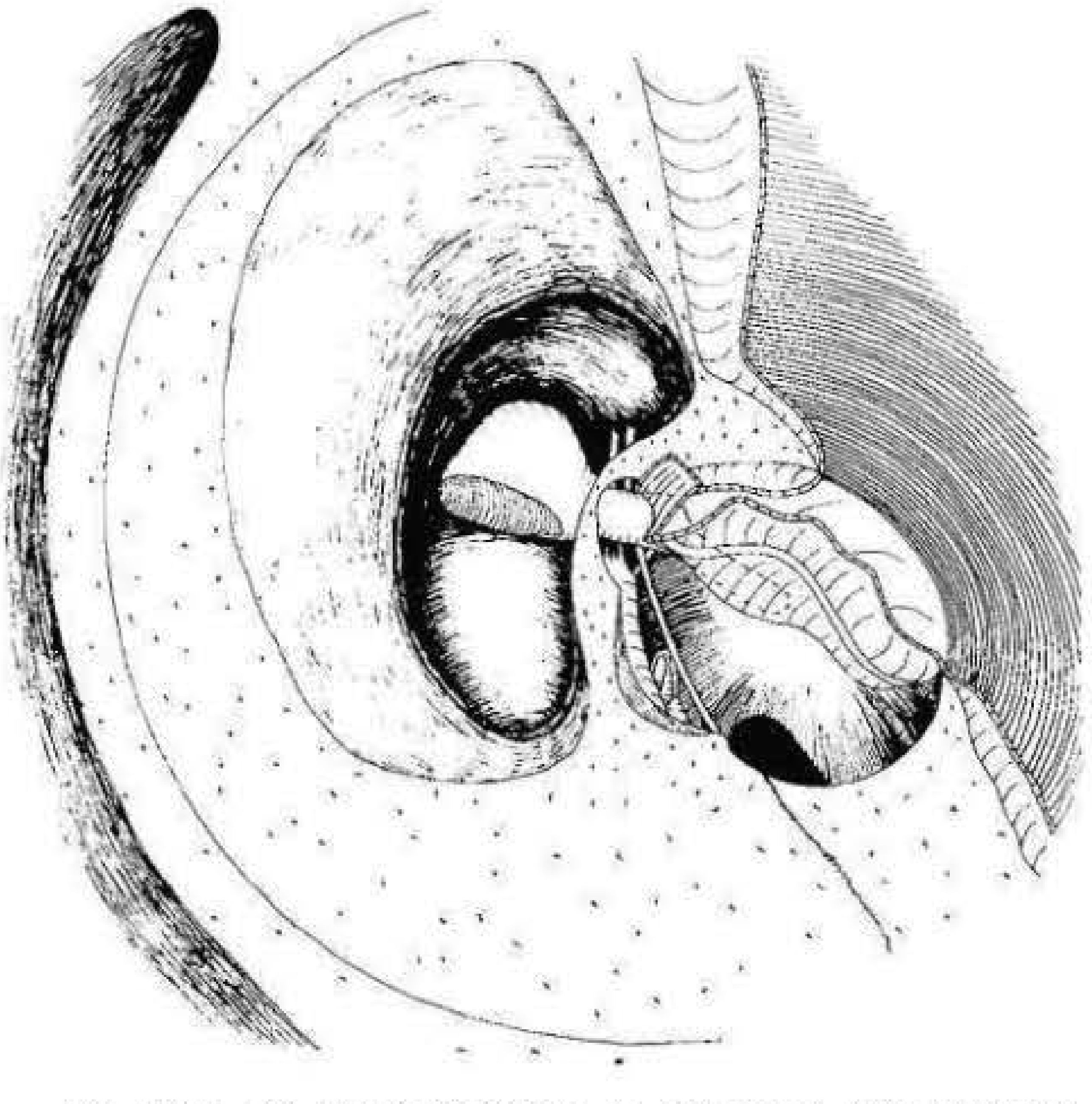


Fig. **449** All cholesteatoma is removed. The malleus head is left in place

Transmeatal Anterior Atticotympanotomy

After removal of the cholesteatoma, an anterior tympanotomy is performed by elevating the anterior fibrous annulus between the 1 and 3-o'clock positions (Fig. **450**), followed by inspection of the anterior tympanum and removal of the tensor tympani muscle fold. Anterior atticotympanotomy is performed with inspection of the epitympanic sinus by removing as much bone as is necessary to create a connection between the attic and the Eustachian tube. This can be achieved by further drilling and thinning of the bony bridge.

After mastoidectomy, as described previously (Figs. **408–414**), cleaning and thinning of the posterior bony ear canal wall and removal of any cholesteatoma in the antrum, bone is removed to provide access to the anterior attic transcortically (Fig. **451**).

Transmastoid drilling of the anterior bony plate, i. e., the cog, establishes the communication between the epitympanic sinus, the Eustachian tube, and the attic.

The anterior atticotympanotomy, whether carried out transmastoidally, transmeatally, or transtympanally, is relatively easy, quick, and safe, because the incus is removed and the malleus head is mobile. However, these procedures should be performed carefully, with the chorda tympani being maintained and the middle ear mucosa preserved as far as possible intact.

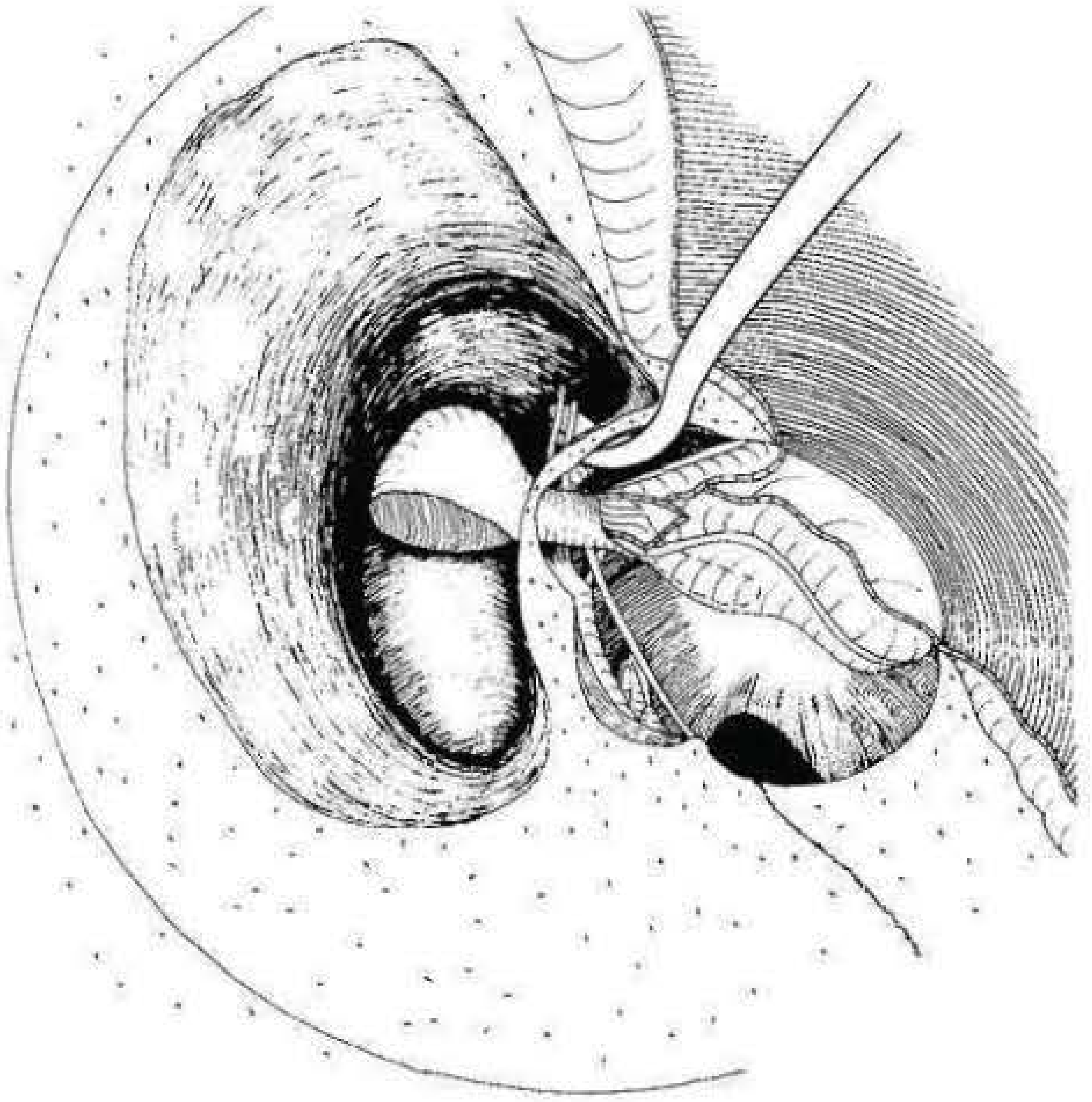


Fig. **450** **Transmeatal anterior atticotympanotomy.** With a curved rugine, the connection between the tympanic cavity and the attic is established

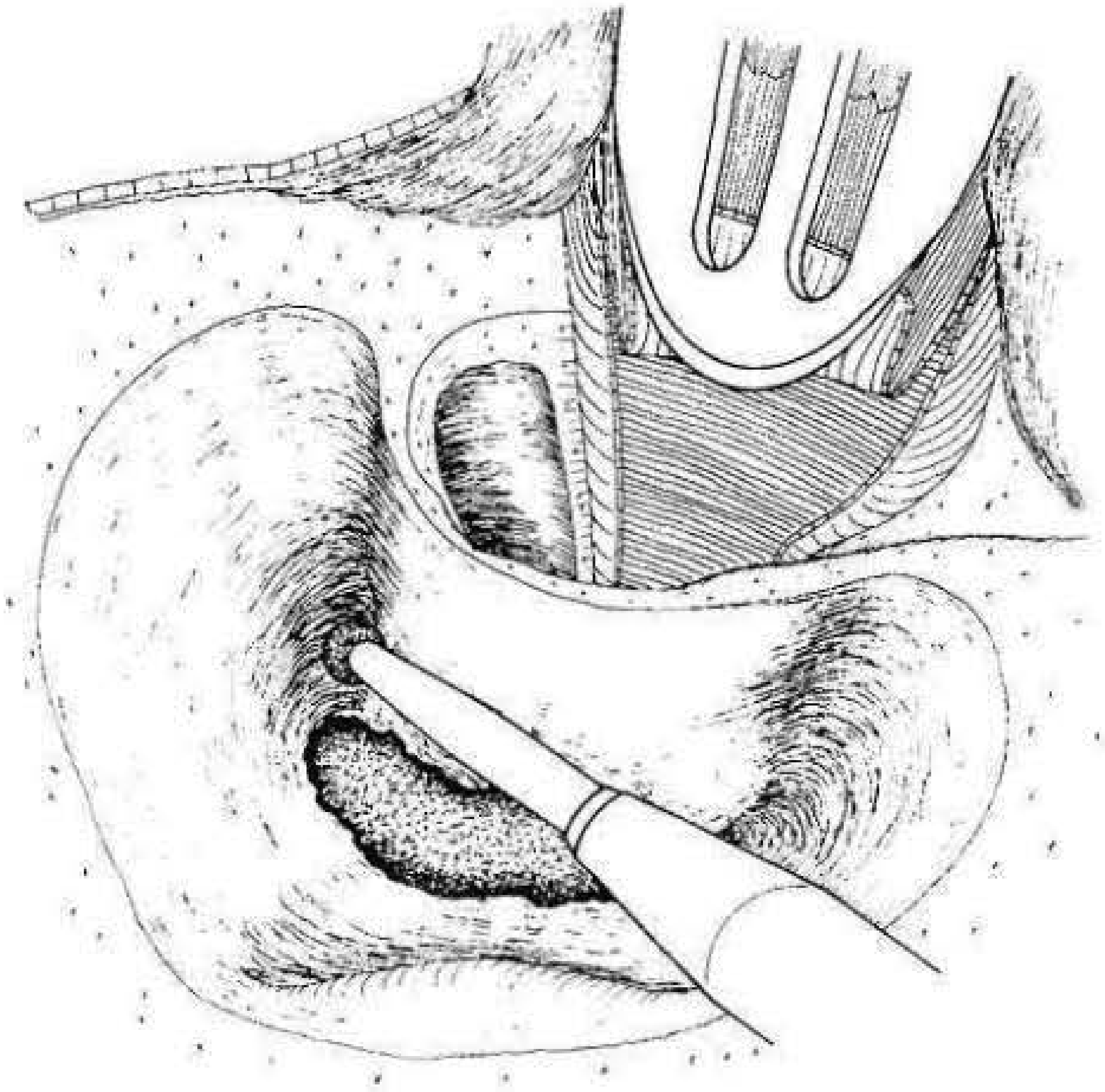


Fig. **451** Modified intact canal wall mastoidectomy with thinning of the posterior bony ear canal wall and removal of the bony overhang anteriorly, in order to gain access for a transmastoid anterior atticotympanotomy

Bougienage of the Eustachian Tube

Bougienage of the Eustachian tube can be performed in various ways (Fig. **425**). Since the 1960s, the author has used soft rubber bougies of 0.5, 0,75, and 1.0 mm thickness. In this particular situation, the bougie can be introduced into the Eustachian tube in the usual way performed in all tympanoplasties, i. e., under the malleus handle, along the eminence of the tensor tympani muscle, and into the tube. The bougie is gently pushed with curved cup forceps (Fig. **452**). Another method is to place the tube into the tubal orifice though the small anterior tympanotomy, i. e., between the bony and the fibrous annulus, at the 2-o'clock position. The bougie tends to follow the same direction along the tensor tympani eminence. A third method is to place it through the anterior atticotympanotomy, between the bridge and the anterior malleolar fold. A fourth method is to place it through the anterior atticotympanotomy under the chorda tympani, i. e., through the tympanic sinus. A fifth method is to place it transmastoidally under the malleus head, under the chorda, and through the epitympanic sinus. If a 0.5 mm bougie passes easily into the tube, it is a good evidence of tubal patency. The bougie may, in some cases, perforate some membranes, but it cannot widen the Eustachian tube.

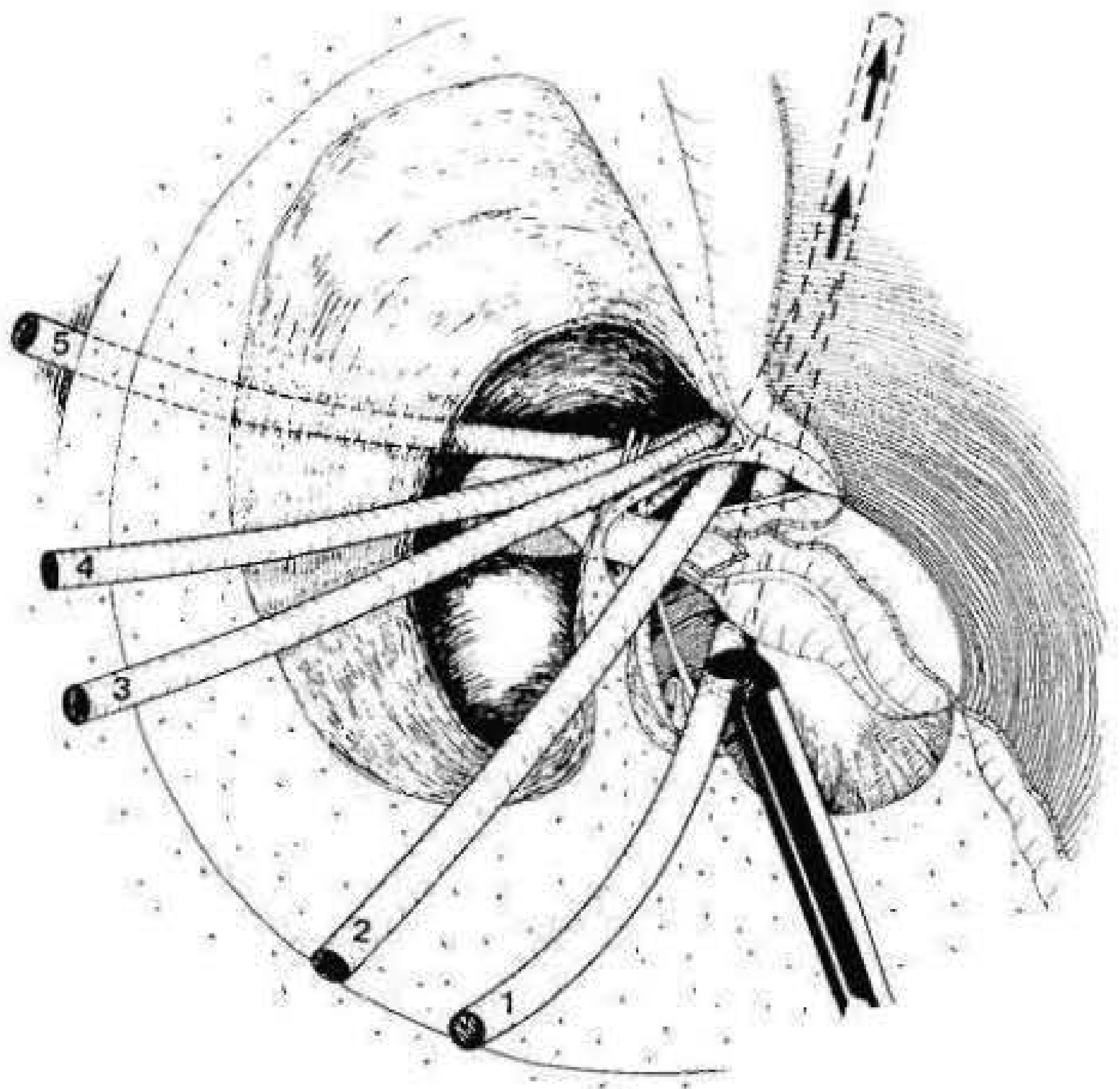


Fig. **452** **Possibilities of bougienage of the Eustachian tube.** 1) A soft rubber bougie is placed transtympanically through the posterior tympanotomy, under the malleus handle, and along the eminence of the tensor tympani muscle. 2) Through the anterior tympanotomy. 3) Through the anterior atticotympanotomy, lateral to the anterior malleolar ligament. 4) Through the anterior tympanotomy, medial to the anterior ligament and chorda tympani. 5) Through the anterior atticotympanotomy by a transmastoidal route, medial to the chorda tympani

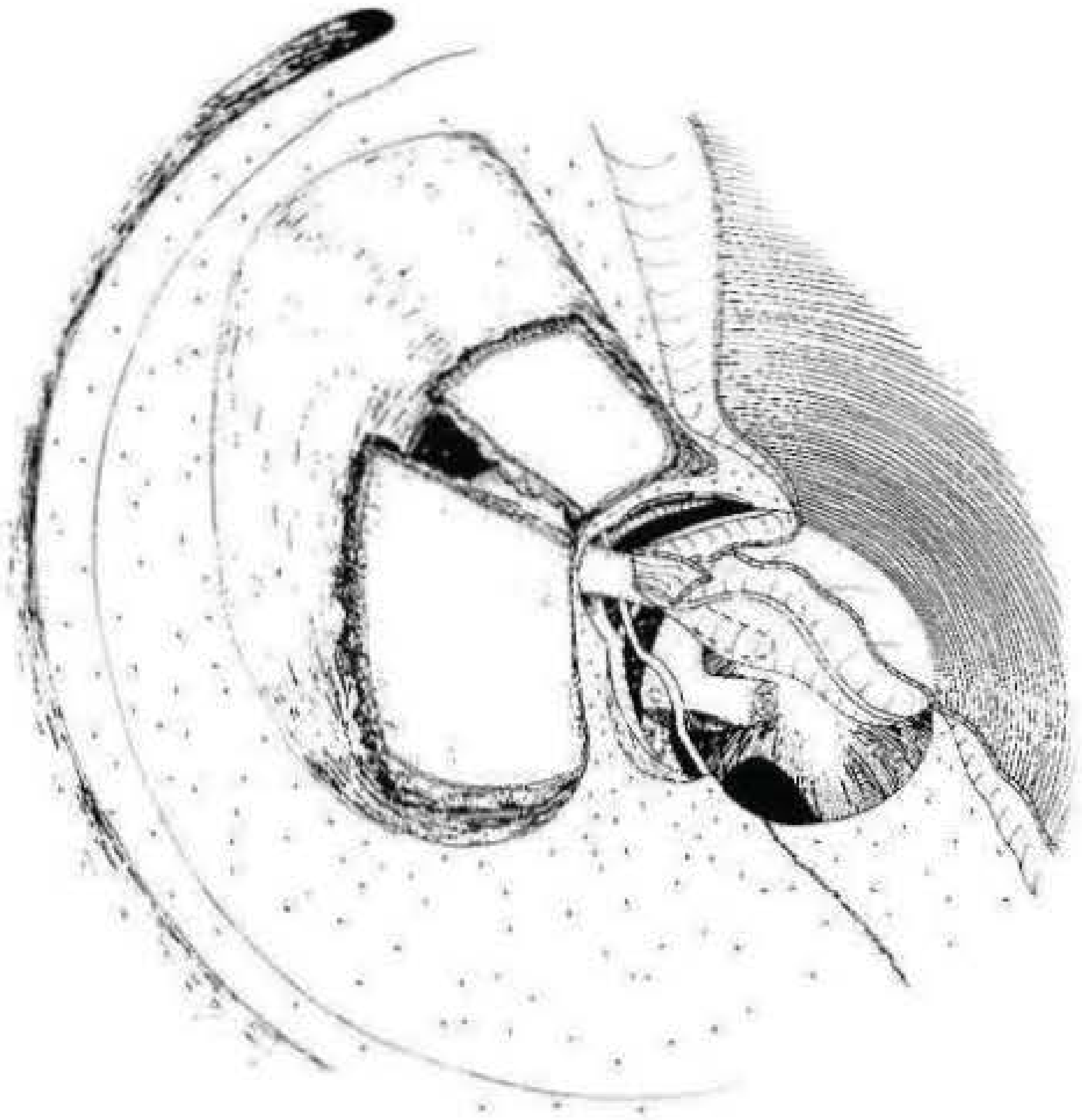


Fig. **453** **Closure of the atticotomy** with two pieces of bone placed in such a way that a small uncovered area persists, providing a view into the attic through the fascia

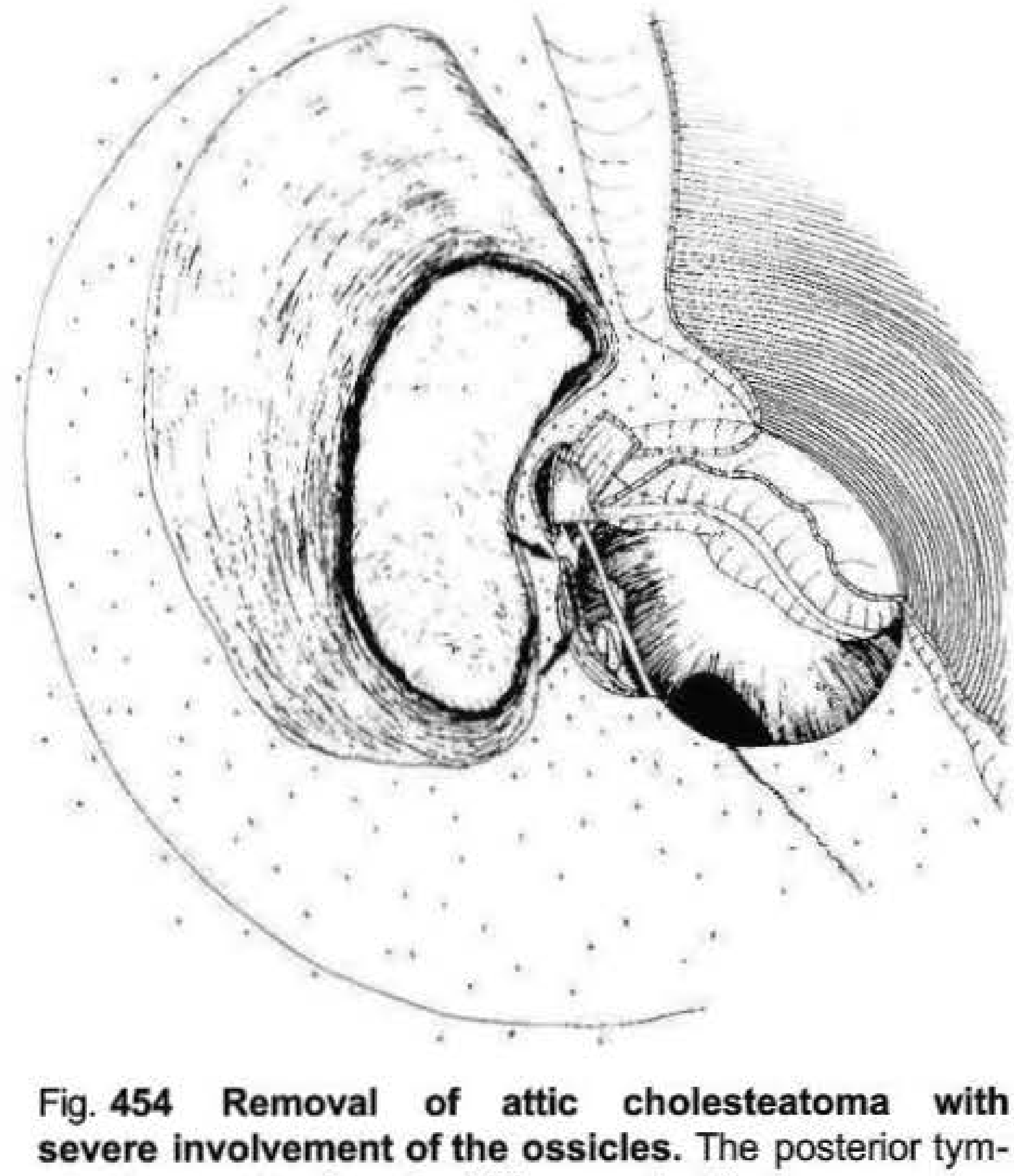


Fig. **454** **Removal of attic cholesteatoma with severe involvement of the ossicles.** The posterior tympanotomy, otosclerosis drilling, and atticotomy are performed. The cholesteatoma surrounding the ossicles and extending from the attic into the tympanic cavity is cleaned, except for its connection with the main cholesteatoma (arrows). A remnant of the incus with the lenticular process is attached to the stapes

Reconstruction

In cases with a missing or defective incus, the author usually preserves the malleus head if it can be cleaned of cholesteatoma and is not initially involved with the cholesteatoma. The author believes that the malleus head prevents deep retraction into the attic, and can possibly maintain ventilation of the attic between the malleus head and the medial wall.

An incus interposition graft is performed (Fig. **453**), and the atticotomy opening is covered posteriorly at the site of the missing incus, either with cartilage or with a piece of bone acquired by chiseling the mastoid cortex. Such bony pieces are particularly well suited to covering the atticotomy opening, because they are multiply fractured and hence curled, often fitting exactly into the atticotomy opening. Anteriorly, a second bony piece may be required. Between the two pieces, the author prefers to leave an uncovered part of the attic in order to facilitate the view into the attic through the fascia. Another possibility is to over the entire atticotomy opening, or its anterior part, with fascia only. Finally, fascia is used to cover the entire atticotomy region, and the tympanomeatal flaps are replaced.

Removal of Large Attic Cholesteatoma Involving the Incus and Malleus

In cases with a large cholesteatoma, the initial stages are the same as those described above. The surgeon follows the extent of the cholesteatoma with a posterior tympanotomy and otosclerosis drilling, in order to get early information about the condition of the ossicular chain, especially as to whether the long process of the incus is defective. A common situation in attic cholesteatoma is a severely eroded incus body but with the lenticular process with the distal part of the long process still attached to the stapes (Fig. **454**), providing excellent hearing due to myringoincudopexy (Vol. 1, Fig. **186**). In such cases, the cholesteatoma usually extends into the tympanic cavity from above, either lateral or medial to the incus body, or may even totally resorb the incus body and enter the tympanic cavity as a broad connection under the bridge. After extensive otosclerosis drilling, the cholesteatoma is removed from the tympanic cavity, the atticotomy is performed, and the incus is dislocated from the malleus (Fig. **455**). The bony bridge is thinned (Fig. **456**), and the cholesteatoma is cleared from the bridge and from the prominence of the facial nerve, before being pushed up into the attic together with the incus. After debulking, the cholesteatoma from the Shrapnell's membrane region and the anterior part of the bridge is cleared, and resection of the head of the malleus is performed with a punch placed superior to the tensor tympani tendon; the chorda tympani is preserved (Fig. **457**). With the resection of the malleus head, the cholesteatoma and the malleus head are freed and can be pushed into the daditus ad antrum, allowing exposure of the medial wall of the attic and further clearing of the cholesteatoma (Fig. **458**). The anterior attic is cleaned, and the transmeatal anterior atticotympanotomy is performed before the posterior attic is also cleaned. The lateral semicircular canal is exposed under the bridge, and the cholesteatoma removal can proceed through the intact canal wall mastoidectomy (Fig. **459**).

The mastoidectomy is performed, the canal wall is thinned maximally, the cholesteatoma is debulked, and final removal can take place (Fig. **460**). Since most of the cholesteatoma has been removed from the attic, final removal is performed as indicated previously (Figs. **424–431**). After

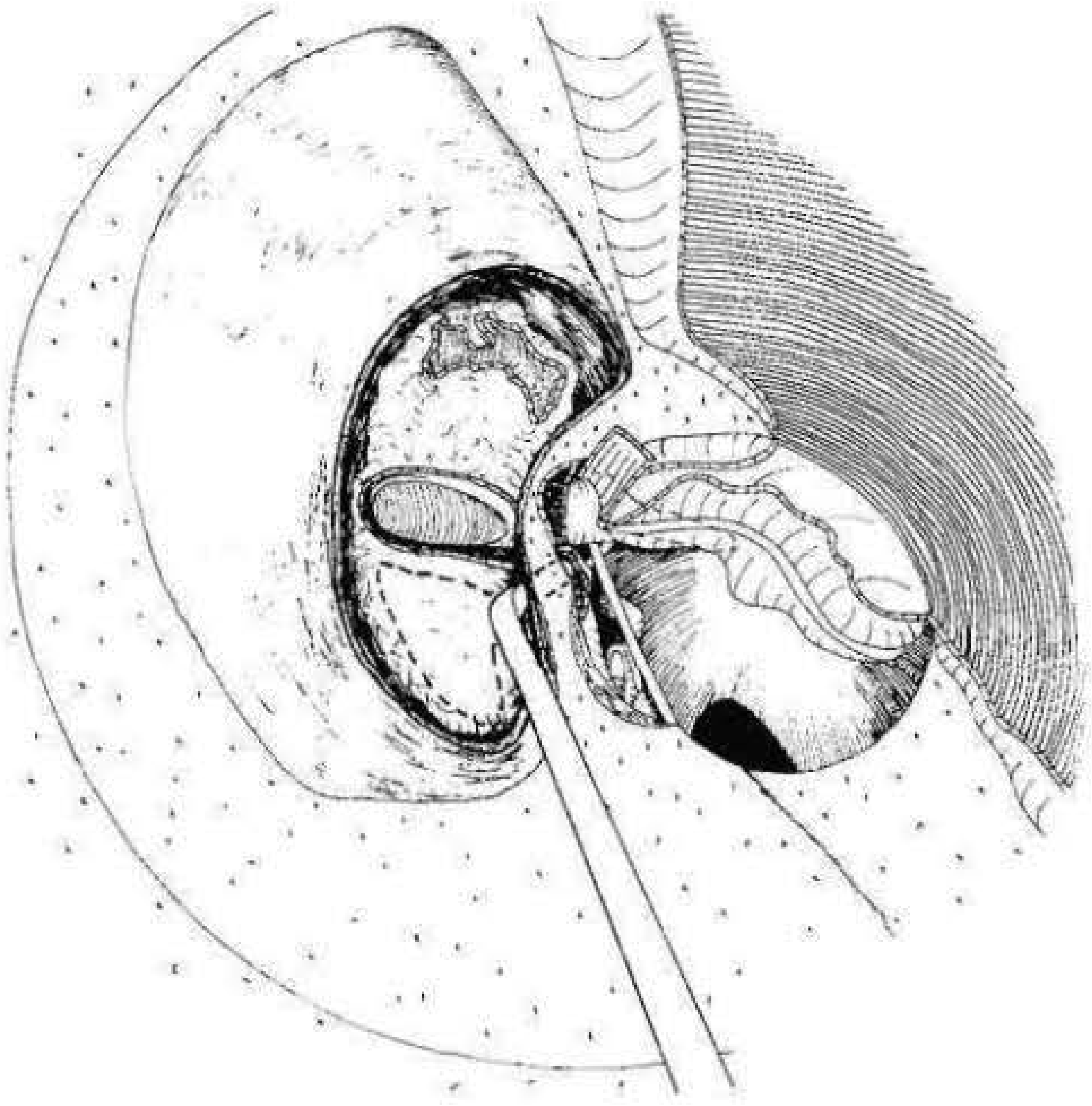


Fig. **455** The extension of the cholesteatoma around the malleus head is visible. The incus is dislocated, and the undersurface of the bridge is cleaned of cholesteatoma

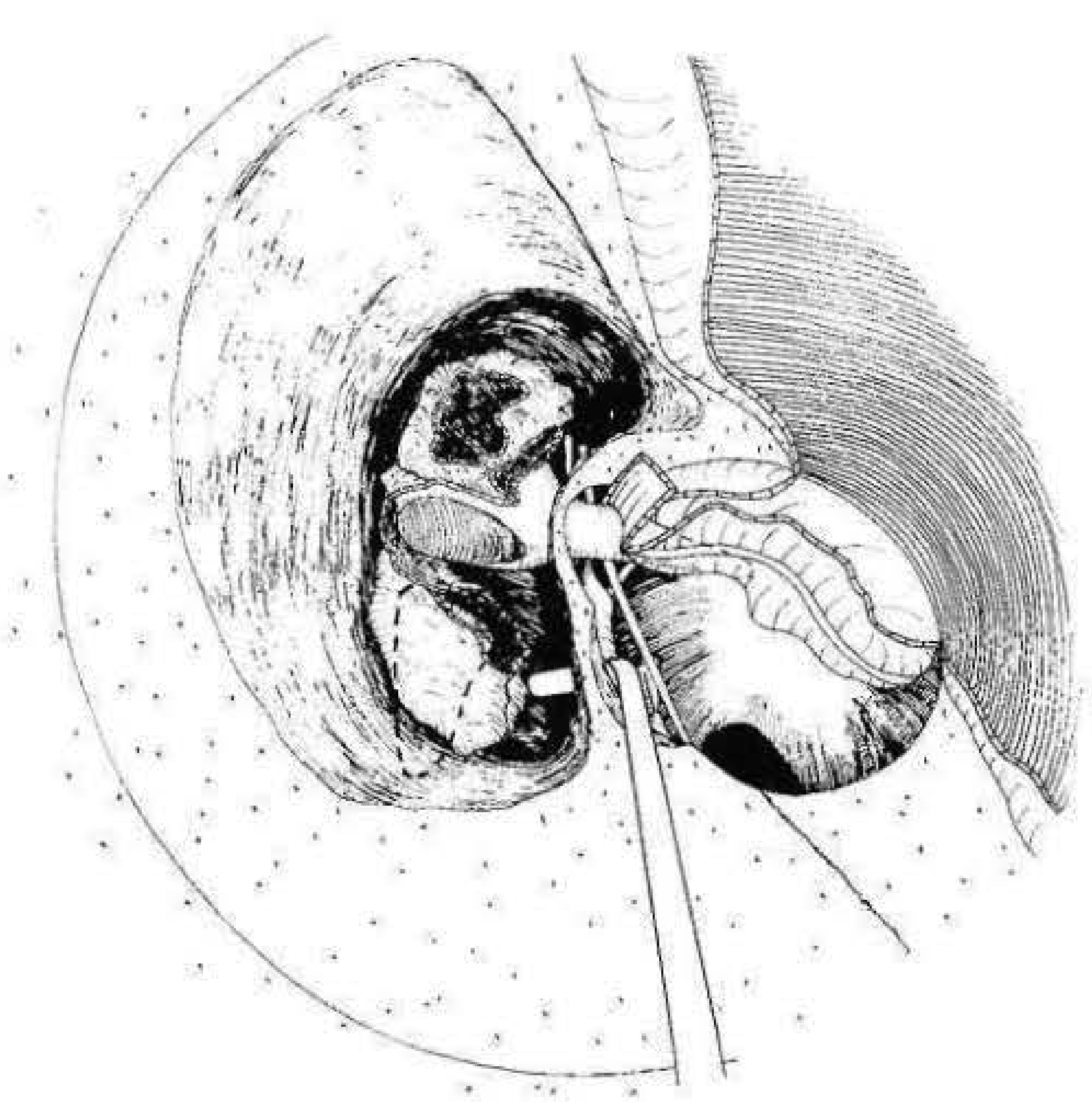


Fig. **456** The cholesteatoma membrane is removed under the bridge all the way around and pushed superiorly, together with the incus remant. The lenticular process is removed

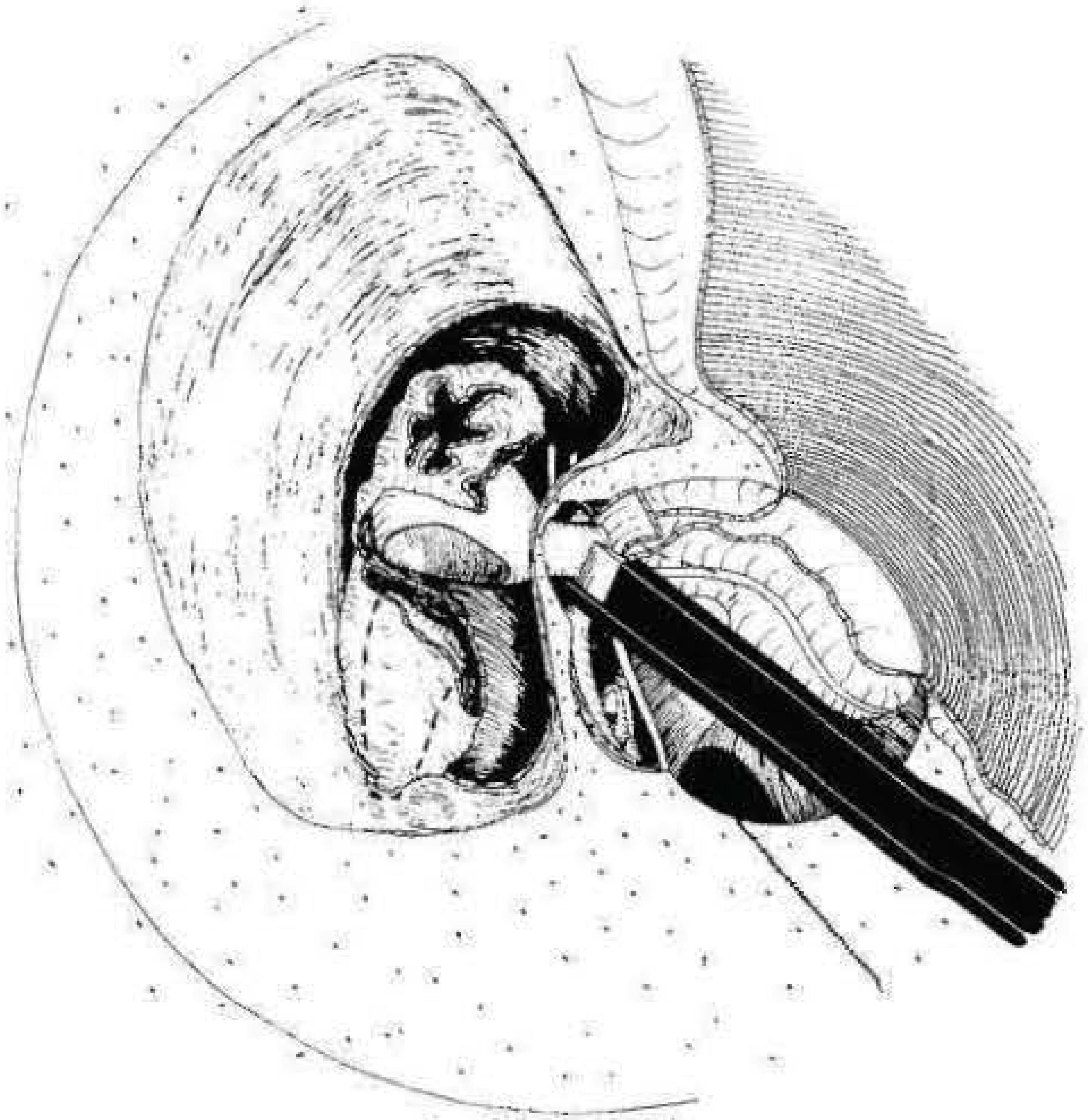


Fig. **457** The neck of the malleus is freed from the cholesteatoma membrane and the head is cut off, using a punch placed under the neck of the malleus, superior to the chorda tympani and the tendon of the tensor tympani muscle

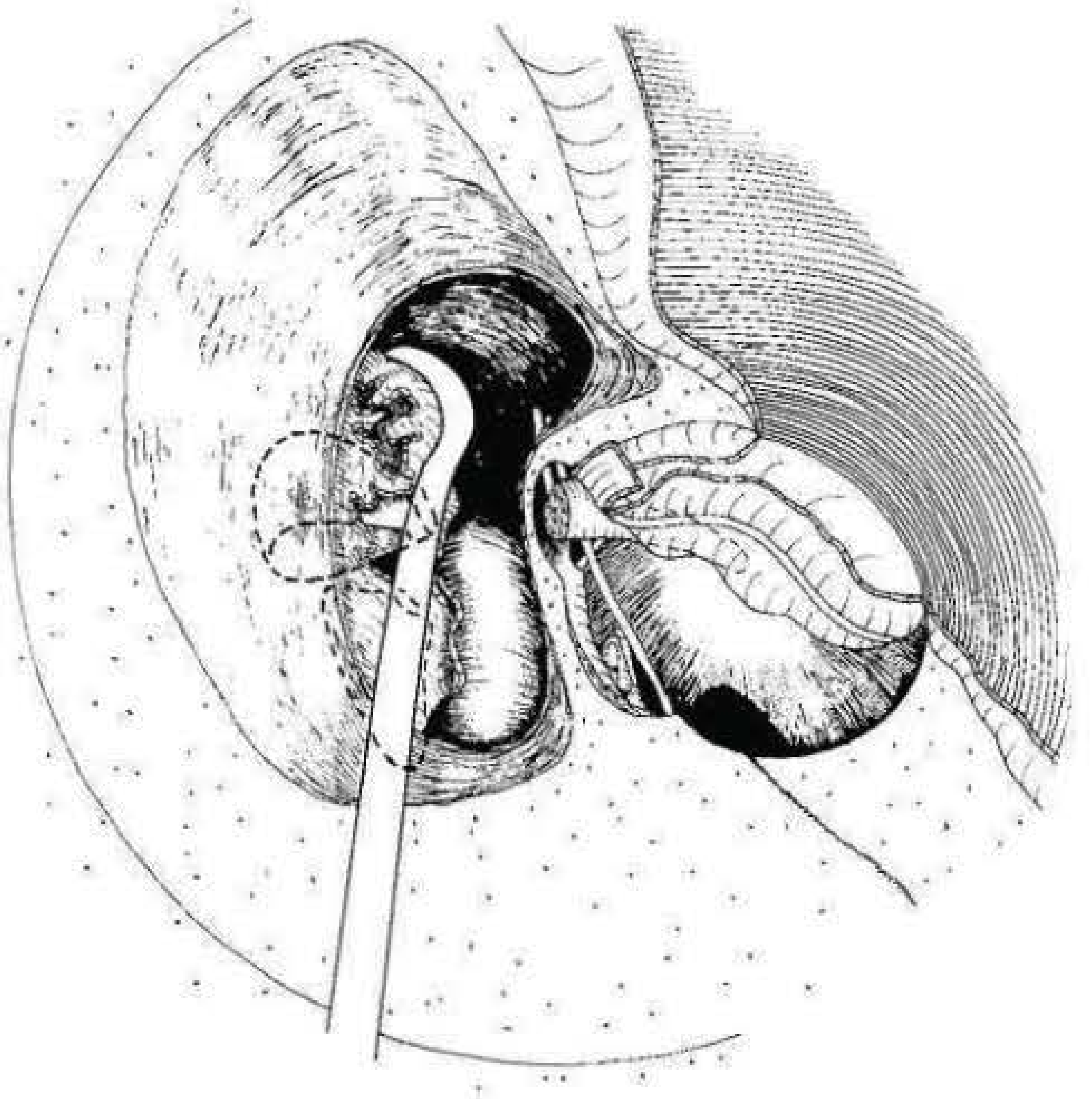


Fig. **458** The remnants of the head of the malleus and the incus are pushed superiorly, together with the cholesteatoma membrane, and will be removed transmastoidally

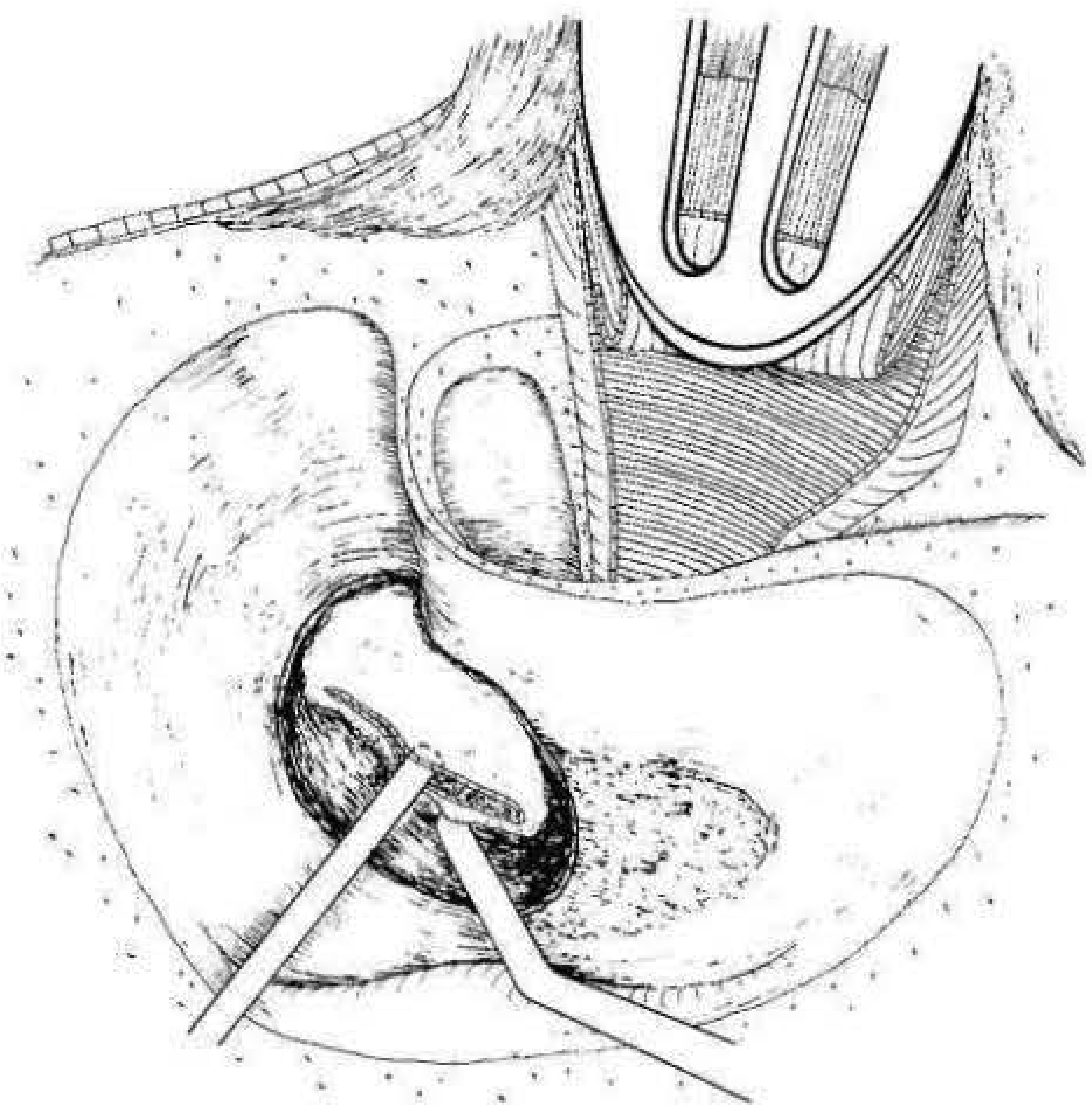


Fig. **459** **Modified intact canal wall mastoidectomy.** The posterior bony ear canal is thinned. The large cholesteatoma in the antrum is opened, debulked, and elevated from the surrounding bone

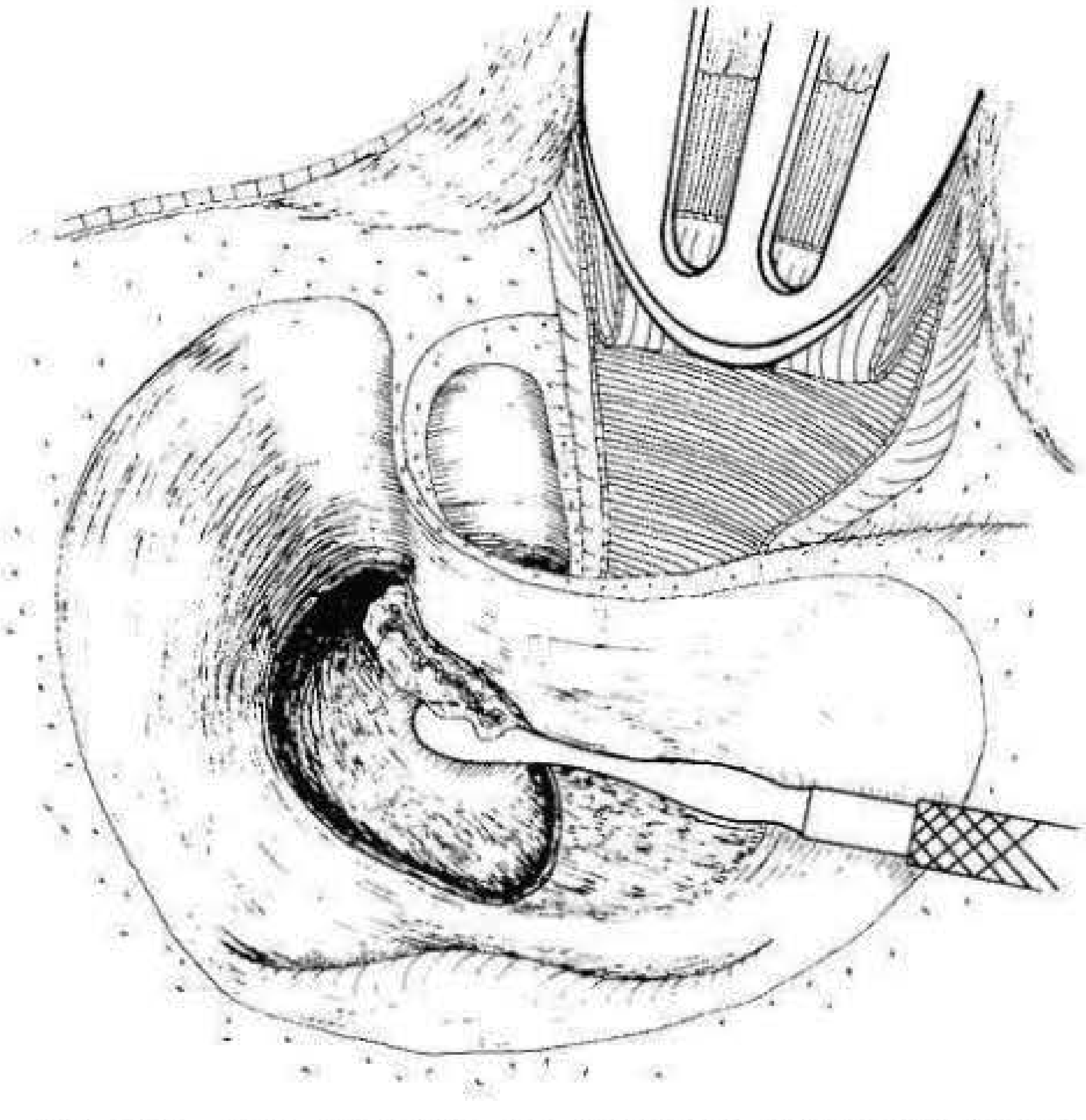


Fig. **460** The ossicles are removed transmastoidally, and the membrane is dissected away from the lateral semicircular canal

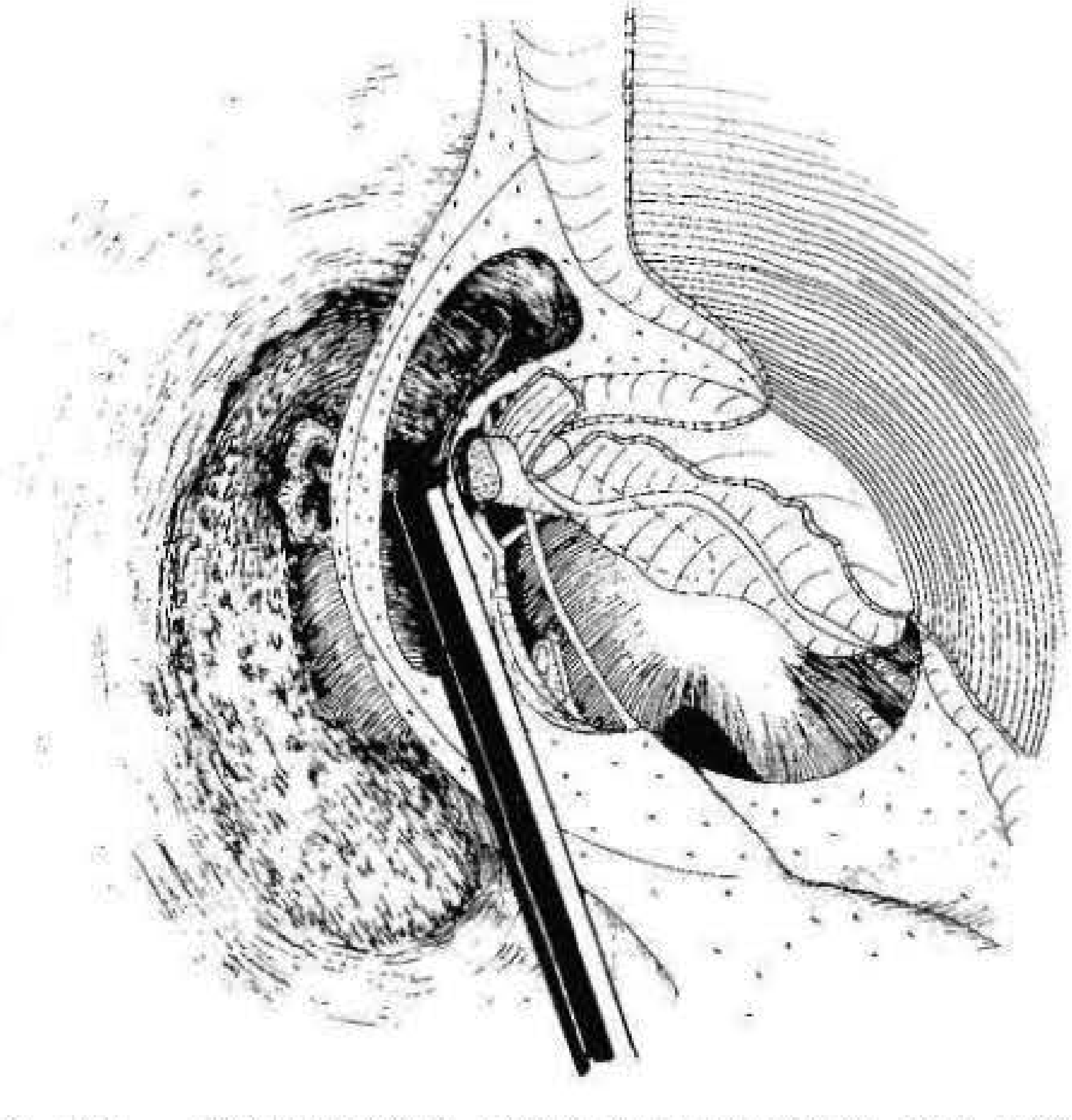


Fig. **461** After cleaning of the cholesteatoma, the last part of the cholesteatoma membrane is removed, leaving an empty attic further cleaning of the lateral semicircular canal and the anterior attic, the final dissection of the cholesteatoma can be safely accomplished from both sides of the preserved ear canal wall, and finally the last remnant removed (Fig. **461**).

Reconstruction of Atticotomy

In cases with a resected malleus head and the incus body removed, retraction between the neck of the malleus and the bridge will eventually lead to a deep, unsafe pocket, but very little can be done to prevent retraction at this site. Covering the atticotomy opening does not prevent retraction between the bridge and the drum.

After ossiculoplasty using a shaped piece of cortical bone placed between the stapes and the incus, the atticotomy opening can be covered in a similar way to that shown previously, either with cartilage (tragal or conchal) or a small piece of cortical bone. Two or three pieces of bone adapted between the bridge and the attic wall ware as good as one large, shaped piece. (Fig. **462**). The author prefers to leave a small fissure between two pieces in order to be able to inspect the attic. Finally, the attic region is covered with fascia placed as an underlay graft under the pars tensa (Fig. **463**), and the skin flaps are replaced. The small malleus flap is placed over the fascia in the attic region (Fig. **464**).

The mastoid cavity is ventilated for three weeks through a tube, which is placed through a separate incision behind the skin incision (Fig. **441**). The ear canal is filled with Gelfoam balls to secure the ear canal skin flaps, as well as a 1-cm wide strip of gauze moistened with oxytetracycline and hydrocortisone ointment. The pack is removed after three weeks. If the Valsalva maneuver is negative preoperatively, the patients are encouraged to perform a Valsalva's maneuver twice a day from the first week.

Postoperatively, retraction may occur (Figs. **465, 466**). The effect of retraction is different in these cases closed with fascia only, when compared with those closed with bone. The retraction surrounds the bridge (Fig. **465a**), which is gradually resorbed, as well as the lower edge of the bony ear canal wall, which may result in a large, selfcleaning, and safe retraction pocket (Fig. **466a**). In cases covered with bone, the retraction is very deep, extending down behind the reconstructed bridge (Fig. **465b**), and may result in an unsafe retraction pocket with insufficient cleaning, leading to retraction cholesteatoma.

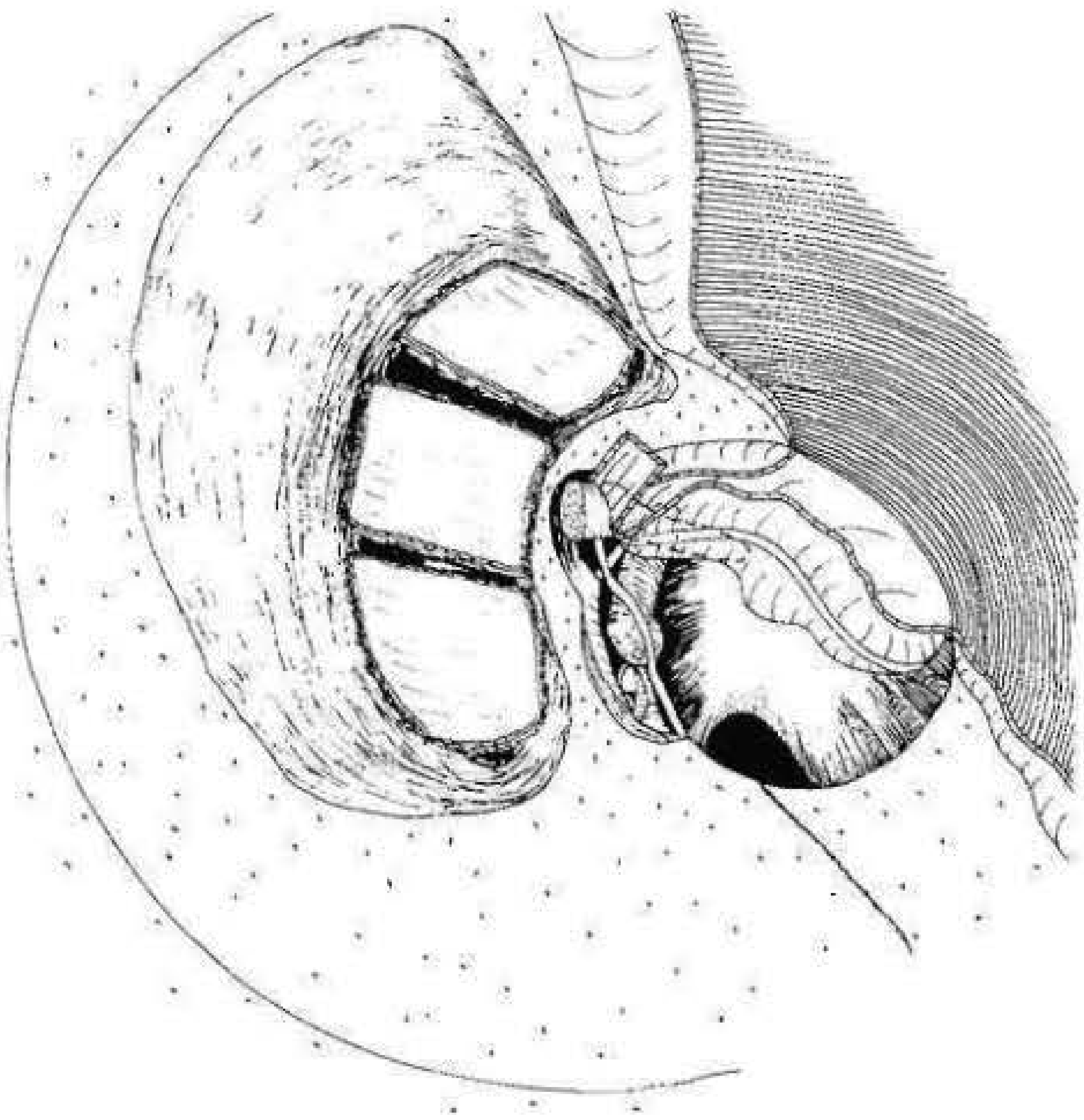


Fig. **462** **Reconstruction of the atticotomy.** The atticotomy is covered with three small pieces of bone, leaving a fissure between the two pieces in order to be able to inspect the attic through the fascia

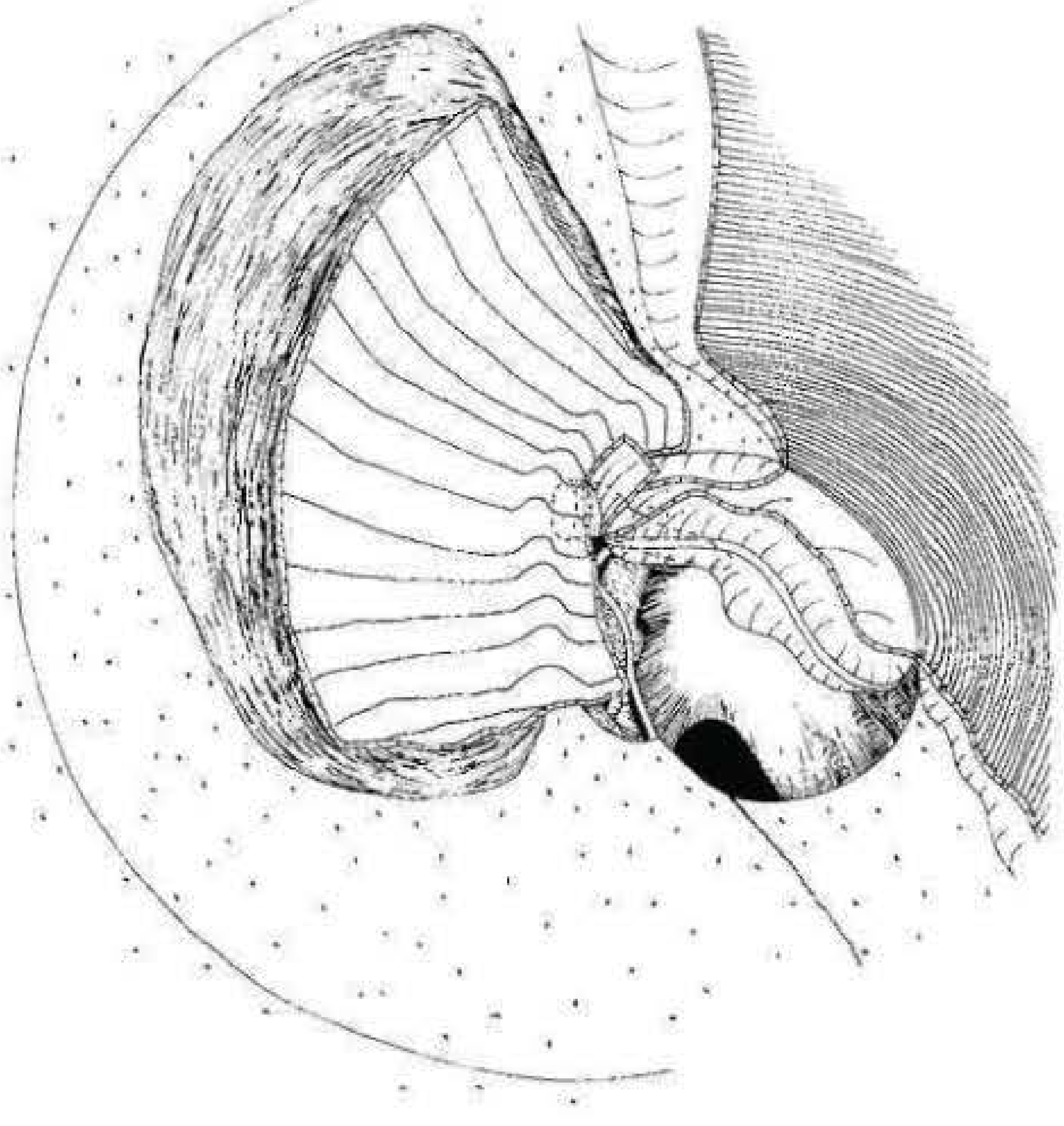


Fig. **463** Fascia covers the atticotomy and the superior part of the tympanic cavity. It is carefully placed on the bridge and the neck of the malleus in order to secure solid replacement of the skin flaps, especially the malleus flap

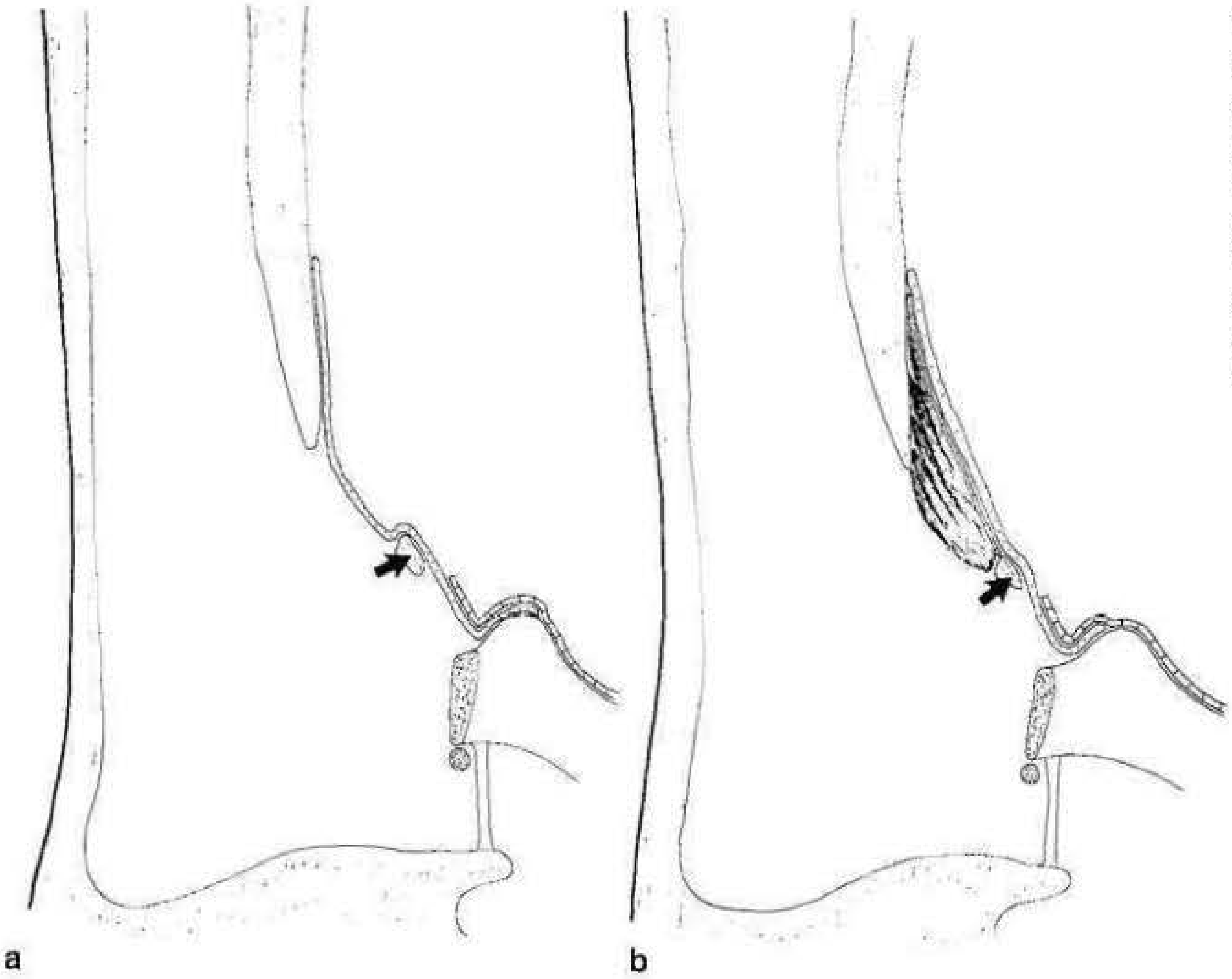


Fig. **464** Side view of an atticotomy, with an empty attic and preserved bridge (arrows). **a** Atticotomy covered with fascia placed on the preserved ear canal, bridge, and malleus neck. **b** Atticotomy covered with bone with the fascia placed on the preserved bony ear canal wall

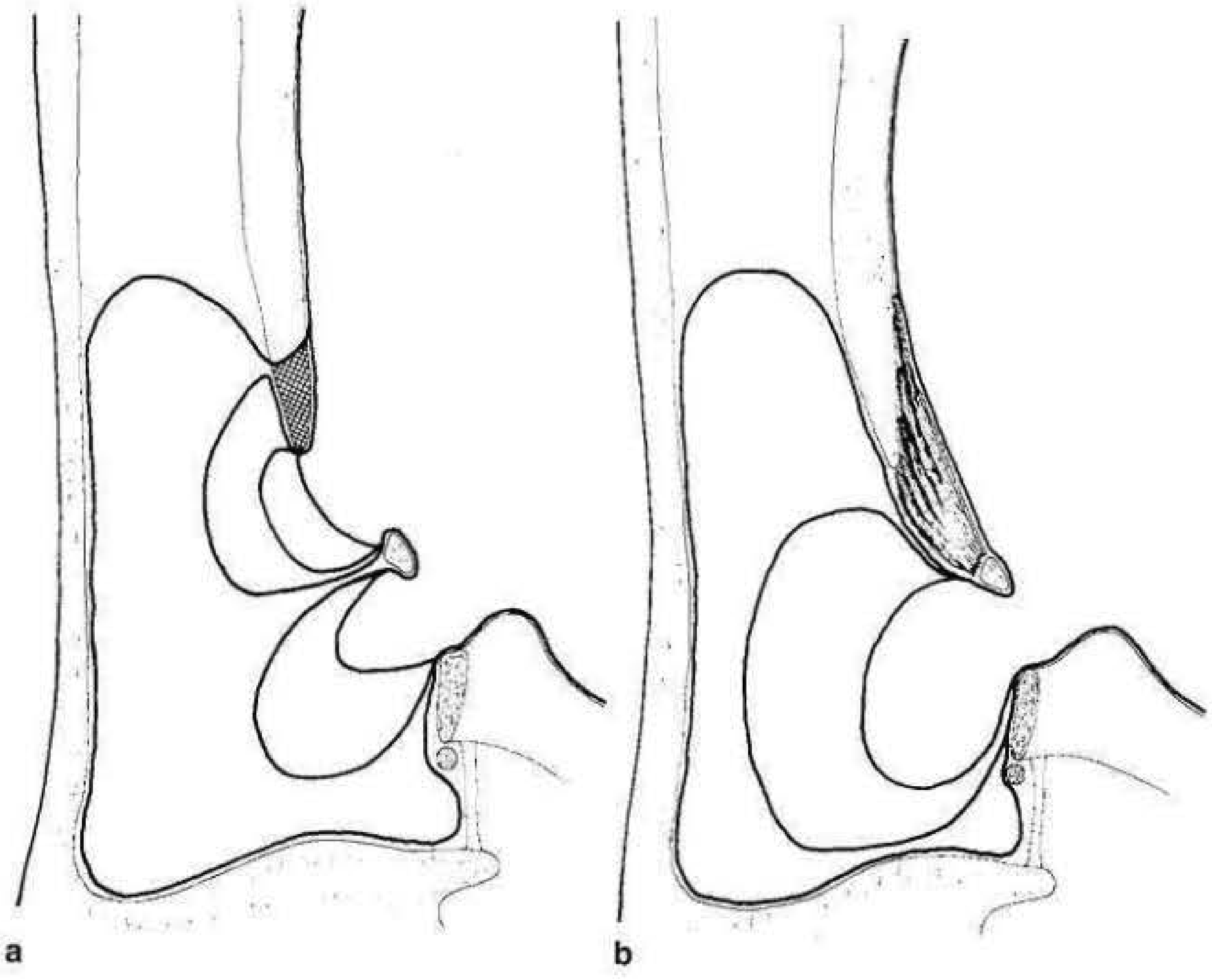


Fig. **465** **Possible postoperative retractions.** **a** After fascial covering, retraction primarily occurs between the neck of the malleus and the bridge, and secondarily at the atticotomy site. The two retractions surround the bridge, which is then resorbed. The inferior edge of the bony wall may be resorbed. **b** After bone covering, a deep retraction inferior to the bridge may occur

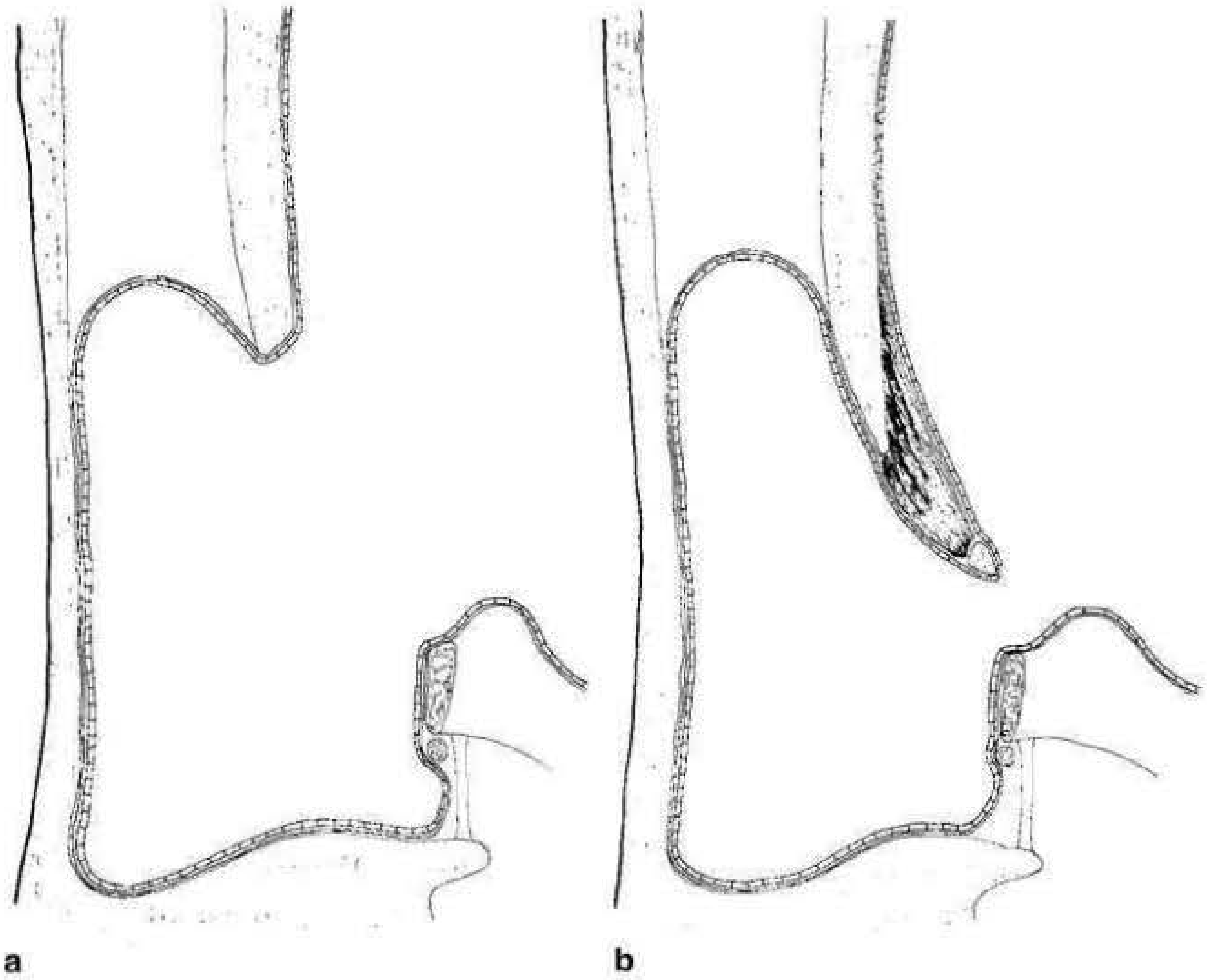


Fig. **466** **Progression of postoperative retractions.** **a** After fascial covering, a large retraction with wide access occurs, due to resorption of the bridge and the medial edge of the bony ear canal wall. **b** After bone covering a deep retraction with small access and a risk for recurrent cholesteatoma may occur

Displacement of the Bridge

In attic cholesteatoma **with either minimal or no spontaneous resorption** of the frame, the atticotomy can be performed with very little change to the shape and location of the bridge, as shown in Figures **467 a** and **402–406.** The same is the case in sinus and tensa retraction cholesteatoma, as well as in all other cholesteatoma types without primary involvement of the Shrapnell's membrane region, and in all cases of noncholesteatomatous chronic otitis in which this technique is applied.

Sometimes the bridge is fractured during surgery, and has to be removed (Fig. **468**). Clearing the cholesteatoma becomes easier, but reconstruction is more difficult, and the risk of retraction is increased compared with cases with an intact bridge. The author therefore recommends preserving the intact bridge if possible. Atticotomy with preservation of the intact bridge is technically more difficult than with removal of the bridge, as is the subsequent removal of the cholesteatoma from the attic, but it is worthwhile to keep the bridge intact.

In attic cholesteatoma **with spontaneous resorption** of the frame and a large primary attic cholesteatoma, the central part of the original bridge becomes resorbed by the cholesteatoma. In ths relatively common situation, there are two possible options available. In the first, a new bridge can be drilled out during the atticotomy superiorly to the spontaneous resorption, resulting in a smaller atticotomy and a superolaterally displaced bridge in relation to its original location (Fig. **468a**). In the second option, the spontaneous defect is further enlarged during the atticotomy, preserving only small remnants of the original bridge anteriorly and posteriorly (Fig. **469).** The author prefers to form a new bridge, even if it is displaced superolaterally. Reconstruction is easier in such cases, and the risk of retraction is smaller, resulting in a better prognosis.

In cases **with extensive spontaneous resorption,** a new superolaterally displaced bridge can again be formed superiorly (Fig. **469 a**). The atticotomy opening is reduced in size, but a good view of the mesotympanum and a reasonable view of the anterior attic can be achieved. The other solution is enlargement of the spontaneously resorbed region and preservation of small parts of the original bridge anteriorly and posteriorly (Fig. **469 b**). Clearing of the cholesteatoma in this situation is easier especially in the anterior attic.

In cases of **very extensive spontaneous resorption,** again a new, superolaterally displaced bridge can be formed (Fig. **470 a**), or only a little of the original bridge can be left (Fig. **470 b**).

In cases **with massive spontaneous resorption.** an atticotomy superior to the erosion will result in a very small opening, so that additional drilling

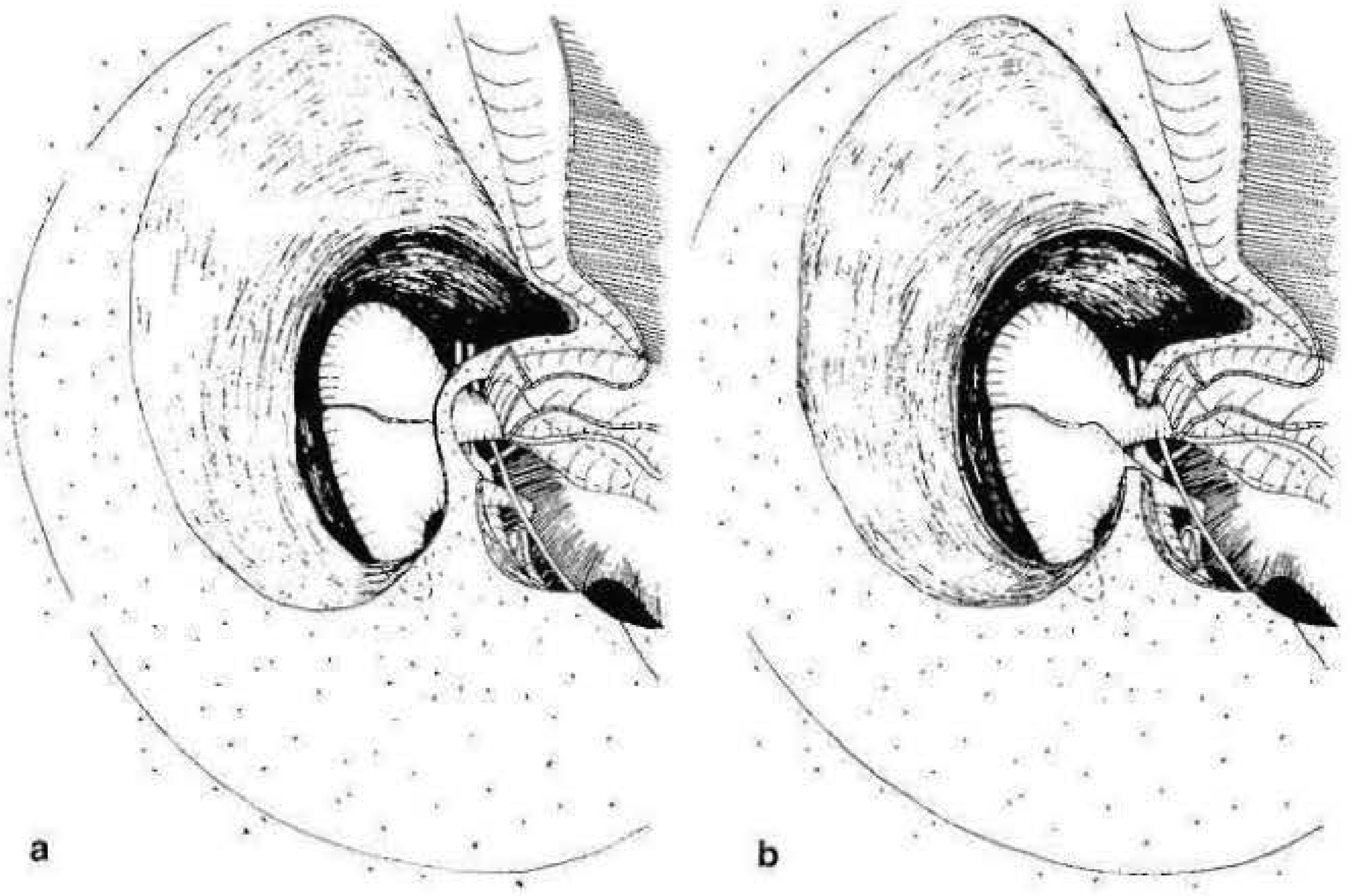


Fig. **467** **Atticotomy without resorption of the frame. a** Atticotomy with an intact, undisplaced bridge, in a case of attic cholesteatoma with no spontaneous resorption of the frame. **b** Fracture of a central part of an undisplaced bridge

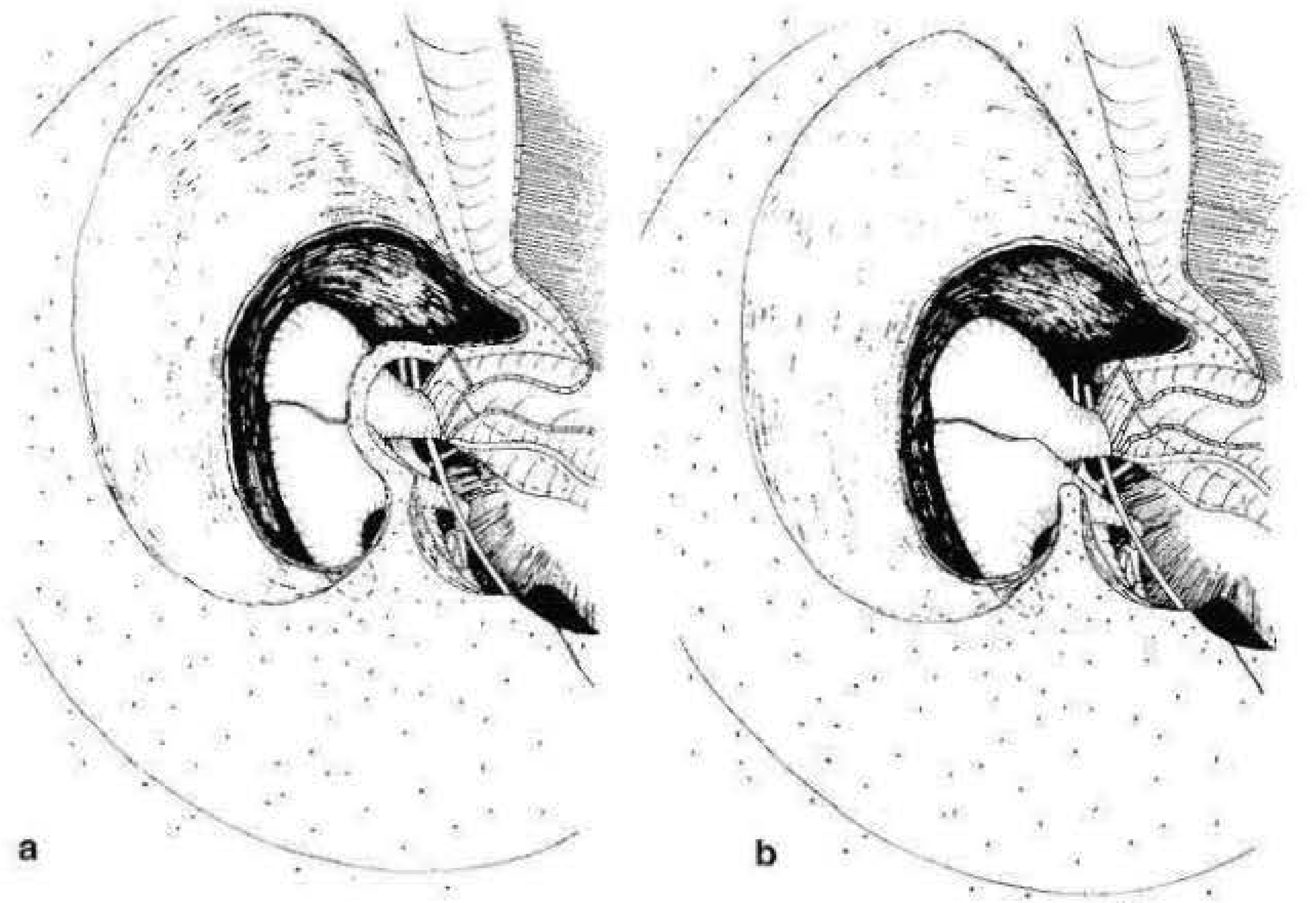


Fig. **468** **Atticotomy with spontaneous resorption of the frame. a** A new, superolaterally displaced bridge is drilled out. **b** Small remnants of the original bridge anterior and posterior to the spontaneous resorption are preserved in the atticotomy

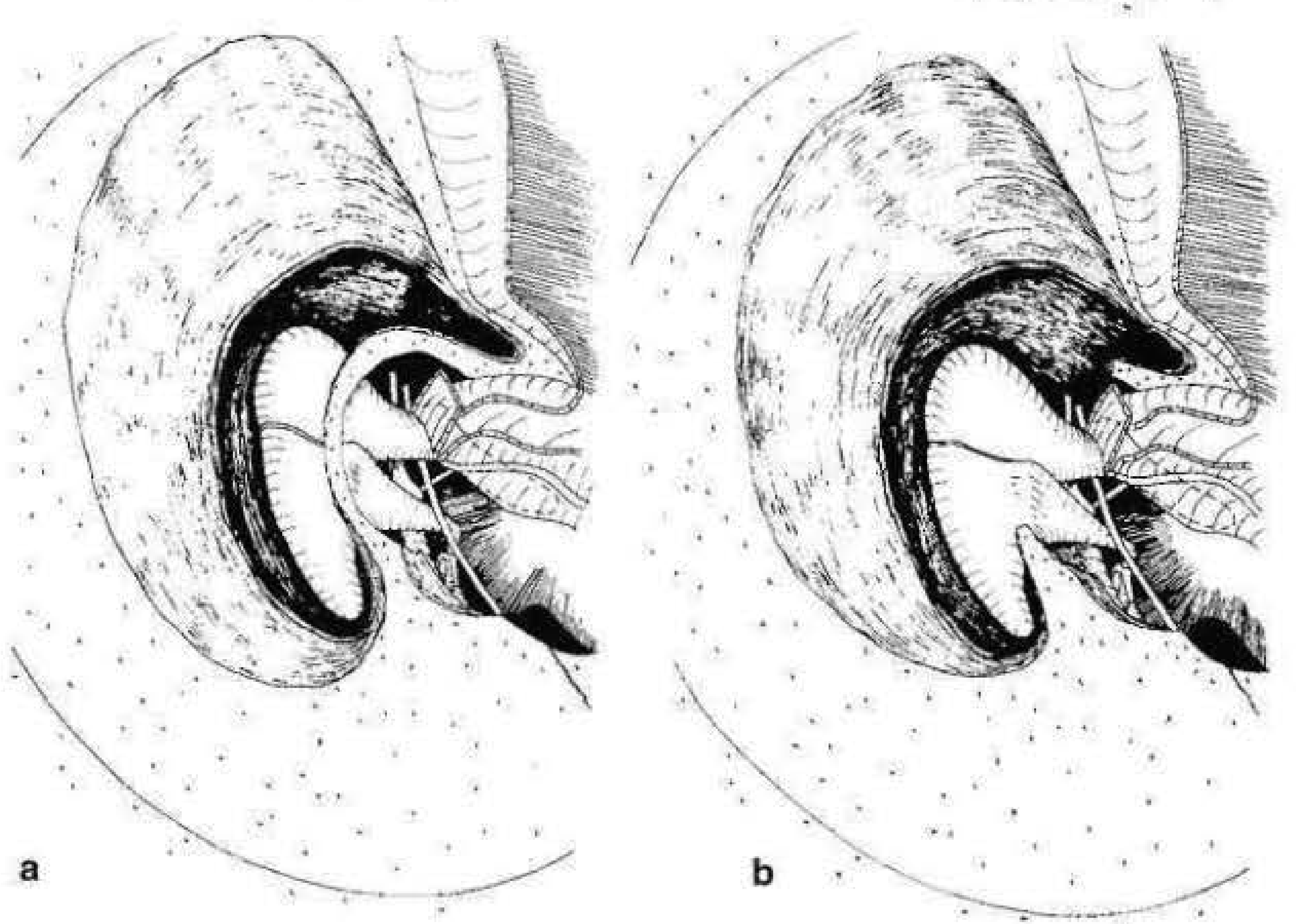


Fig. **469** **Atticotomy in large spontaneous resorption of the frame. a** The atticotomy is performed superior to the new bridge, which is displaced superolaterally in relation to the original one. **b** Small parts of the original bridge are preserved anterior and posterior to the spontaneous resorption in the atticotomy

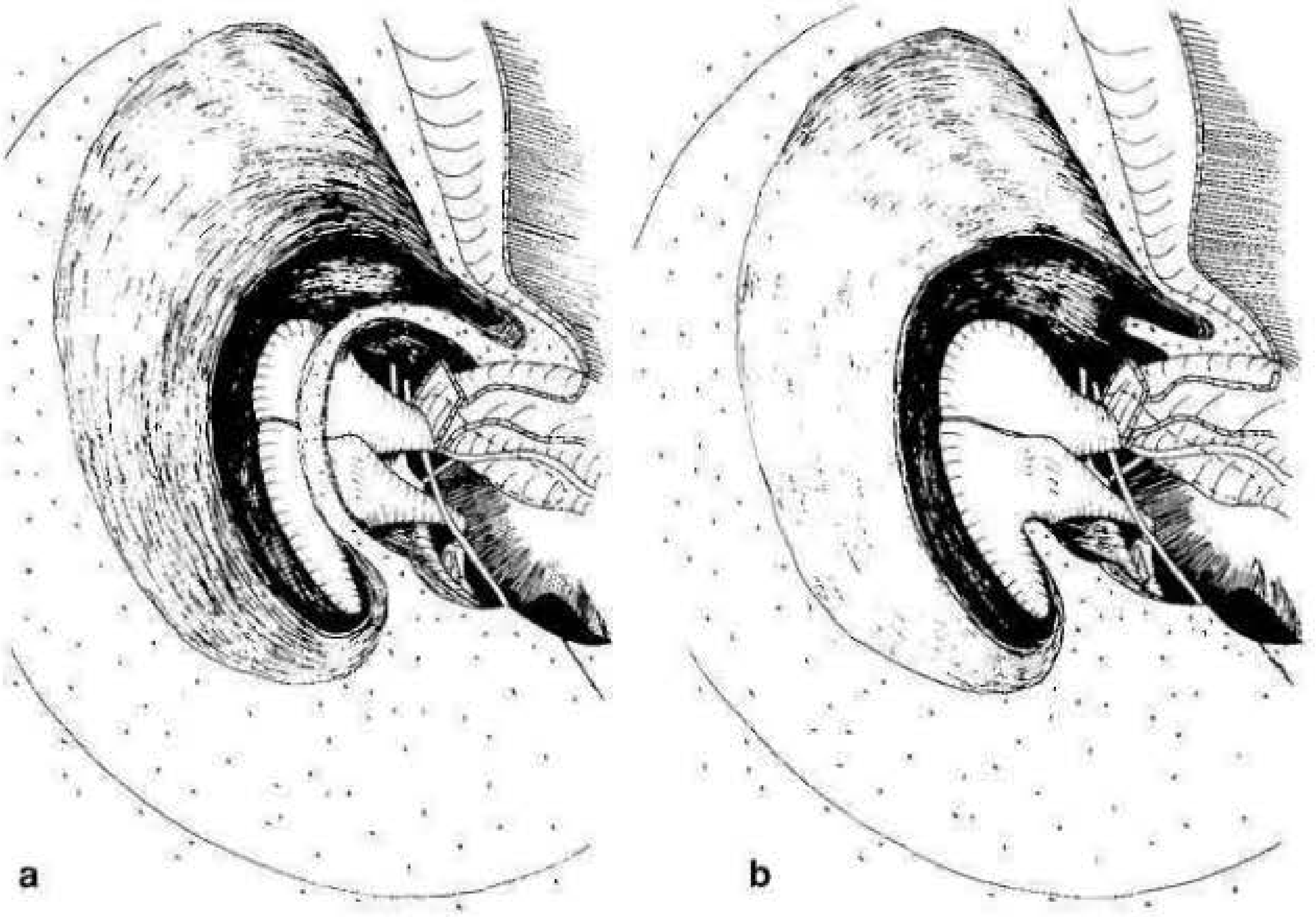


Fig. **470** **Atticotomy in very large spontaneous resorption.** **a** A small atticotomy superior to the new, superolaterally displaced bridge. **b** Remnants of the original bridge anterior and posterior to the spontaneous resorption in the atticotomy

toward the tegmen tympani is necessary, and the dura may be exposed. The bridge is therefore again displaced superolaterally (Fig. **471a**). Enlarging the spontaneous resorption will result in a very small bridge (Fig. **471b**).

The subsequent mastoidectomy and thinning of the bony ear canal is less extensive in these cases, because the extended atticotomy has already exposed the tegmen tympani and displaced the bony ear canal (Fig. **472**).

The bony ear canal will be displaced posteriorly, and there will be either very little or no space between the anterior part of the mastoid tegmen and the displaced bony ear canal wall. The author's method, attempting to preserve the bridge and repneumatize the mastoid cavity, is therefore gradually transformed into another method with widening of the ear canal and displacement of the bony ear canal wall (Figs. **46, 47**) as originally described by Farrior (1968, 1973) and termed "anterior transcanal atticotympanotomy with posterior mastoidectomy."

This method is described in Chapter 10.

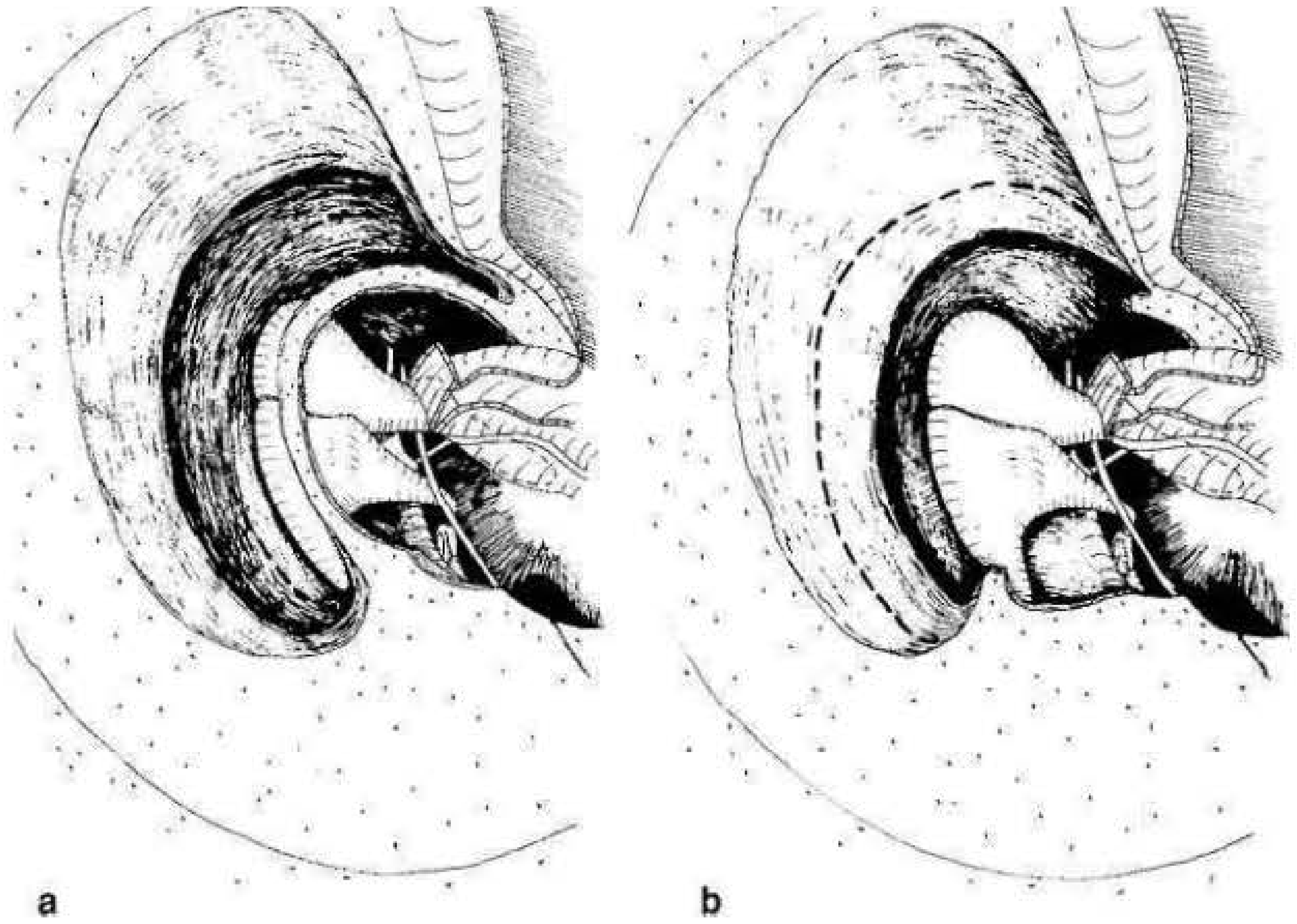


Fig. **471** **Atticotomy in huge resorption of the frame.** **a** By further drilling towards the tegmen tympani, a relatively large atticotomy is performed superior to a new superolaterally displaced bridge. The dashed line indicates the superior extension of the atticotomy without displacement of the bony ear canal. **b** Enlargement of spontaneous resorption into a large atticotomy, with small remnants of the original bridge anteriorly and posteriorly. The dashed line indicates the additional drilling necessary for preservation of a displaced bridge

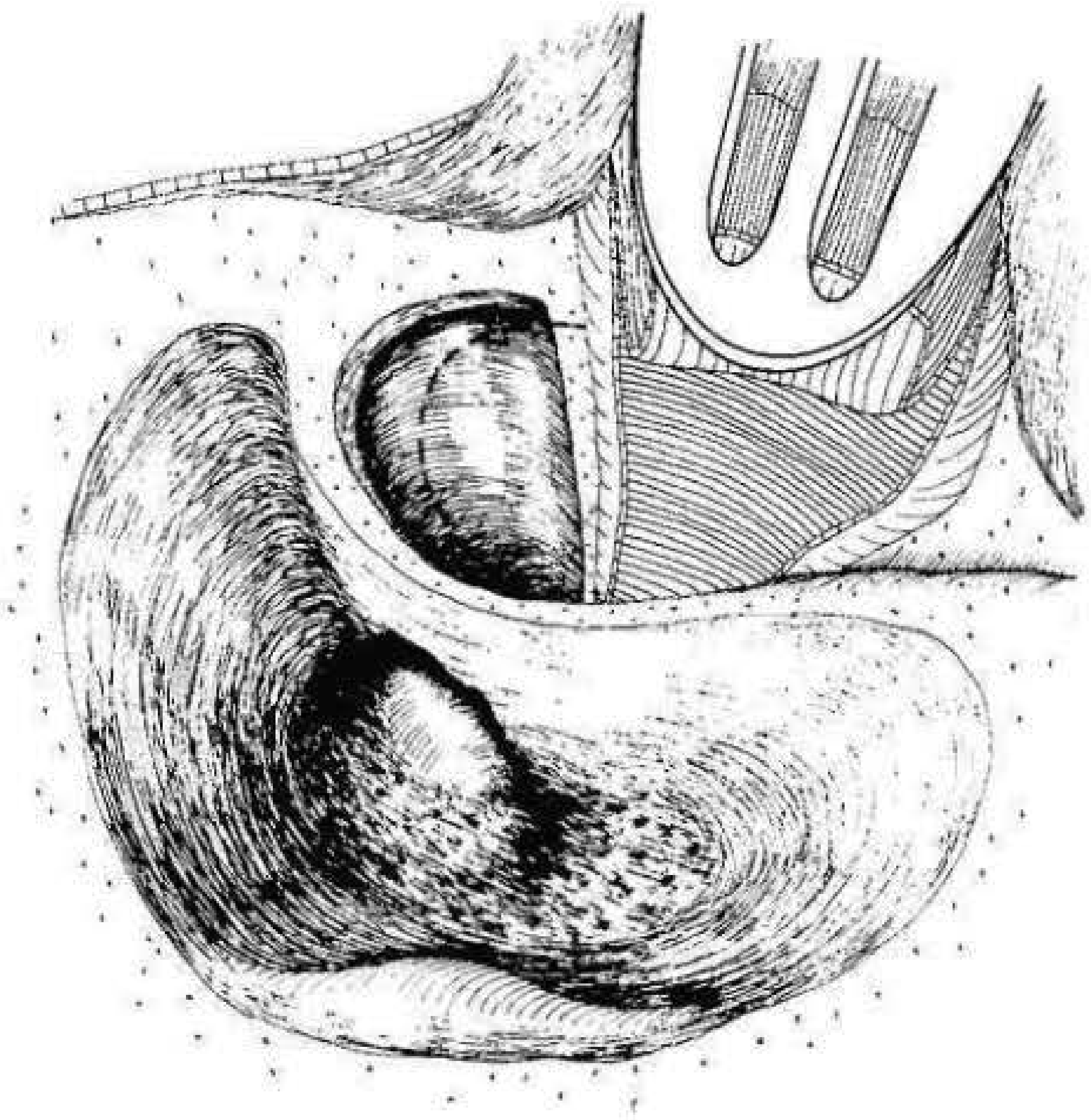


Fig. **472** **Posterior displacement of the bony ear canal wall.** Modified intact canal wall mastoidectomy in a case with extended atticotomy and superolateral displacement of the bridge. Because of the extended atticotomy, the bony ear canal wall is displaced, and the anterior part of the mastoidectomy drilling is not necessary. The incus is missing, and the malleus head has been resected. Dashed line indicates the original position of the ear canal wall

Reconstruction of the Atticotomy with a Displaced Bridge

The atticotomy in cases with a displaced bridge can be covered with fascia, cartilage, or cortical bone. In cases with an intact, but displaced bridge (Figs. **468a, 469b, 470a, 471a**), there is no problem covering the atticotomy opening superior to the bridge, since no retraction will occur at this site (Fig. **473**). This is in contrast to the significant risk of retraction inferior to the bridge, since there is no support between the bridge and the neck of the malleus.

In cases with an intact ossicular chain — which seldom occurs — the fascia retracts onto the head of the malleus and incus body, and the situation may remain stable (Fig. **473**). With a missing malleus head and incus body (Fig. **474**), the fascia may retract into the empty attic and around the neck of the malleus. If the malleus head is preserved, the retraction may be less deep than in cases without the malleus head (Fig. **475**). In spite of closure of the atticotomy being carried out with pieces of cortical bone or tragal cartilage (Fig. **476**), the problem of retraction inferior to the bridge still exists. This region can be covered with small palisades of conchal cartilage or slices of tragal cartilage placed under the fascia covering the region. Any attempt to cover the defects of the bridge with a piece of bone will not provide a firm and stable structure.

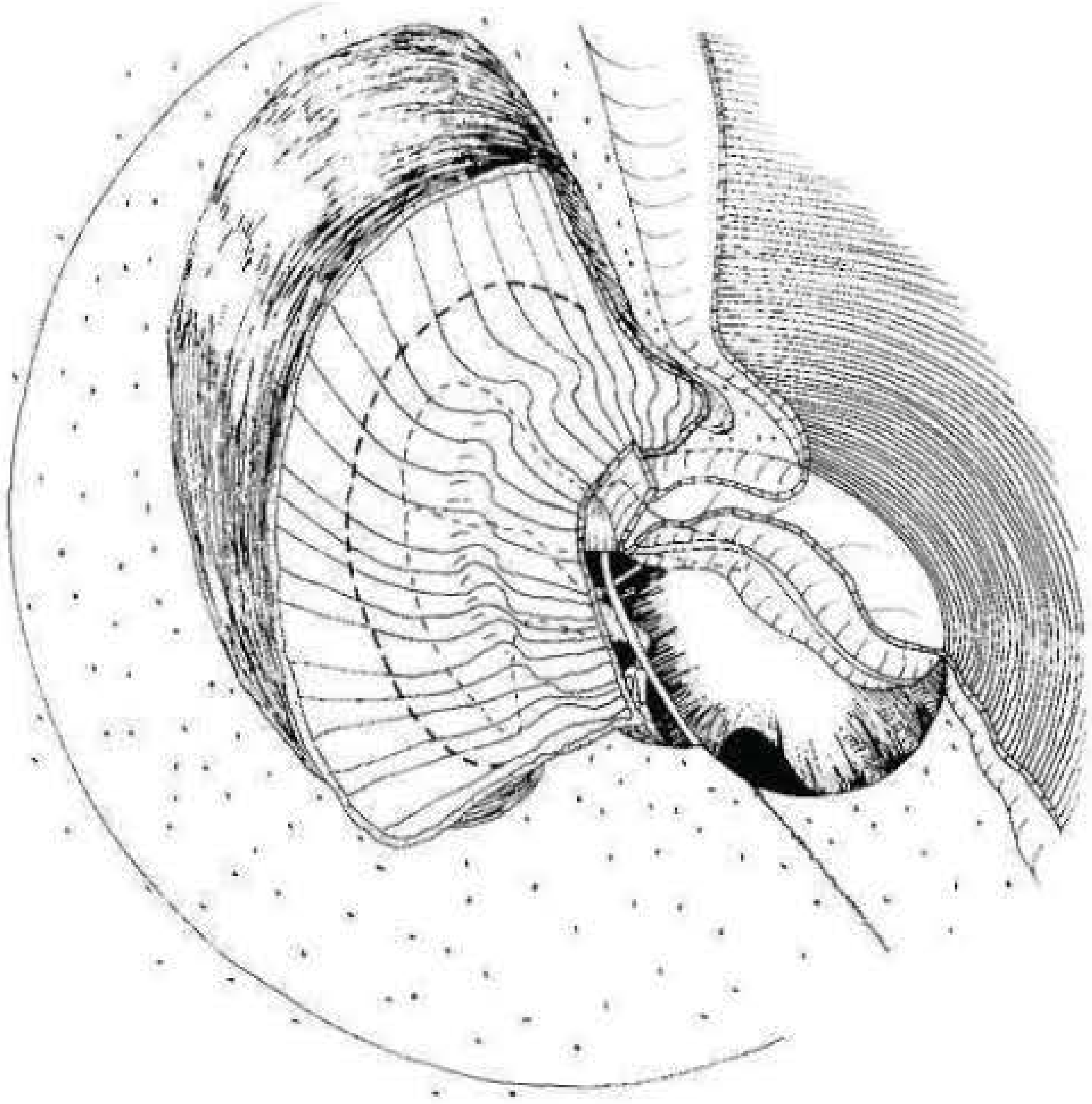


Fig. **473** Covering of an atticotomy with fascia in a case of a laterosuperiorly displaced bridge. Fascia is placed under the drum remnant onto the incus, the neck and head of the malleus, and onto the bridge

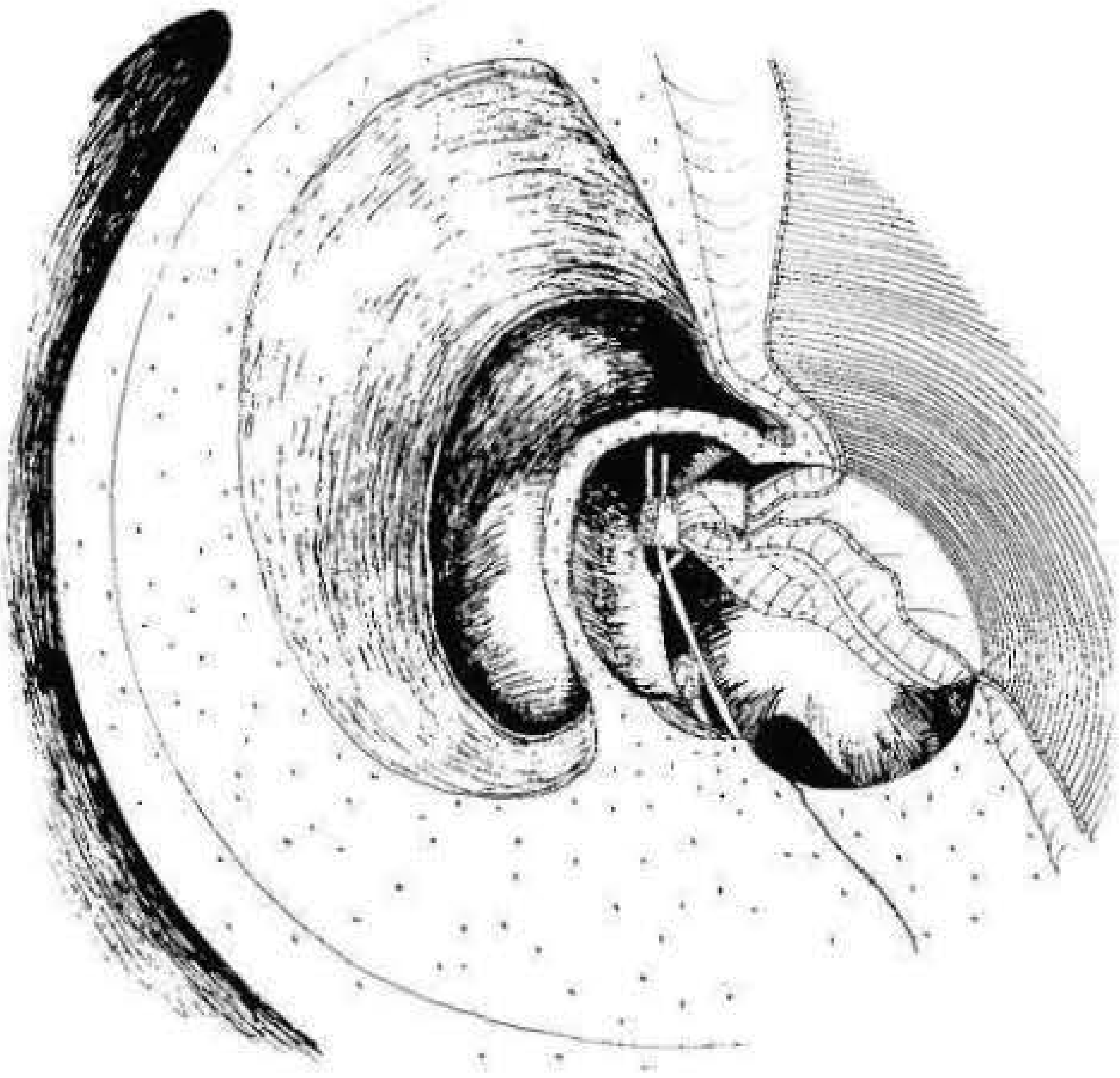


Fig. **474** A situation after atticotomy with superolateral displacement of the bridge and an **empty attic**, due to resection of the malleus head and removal of the incus body. Even if a solid reconstruction of the atticotomy superior to the bridge is applied, the risk for retraction nferior to the bridge is great

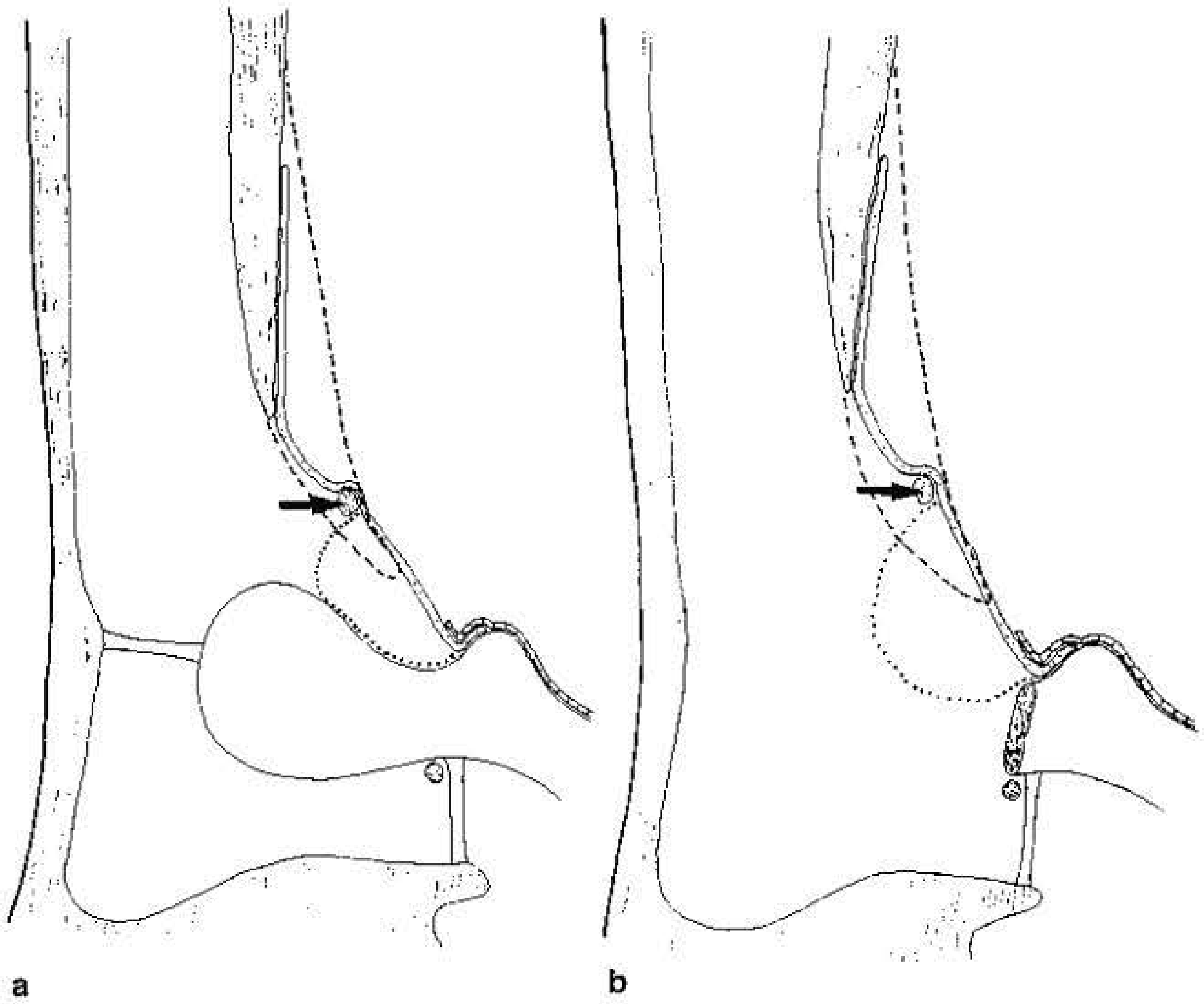


Fig. **475** **Side view of fascial covering of an atticotomy with superolateral displacement of the bridge** (arrows). The position of the original ear canal is indicated by the dashed lines. **a** With an intact malleus, indicating a stable situation in case of retraction onto the malleus head (dotted line). **b** With a resected malleus head, indicating a high risk for a deep, unsafe retraction (dotted line)

Reconstruction of the Atticotomy with a Missing Bridge

Covering the atticotomy openings in cases of missing bridge and intact ossicular chain (Figs. **467 a, 468 b, 469 b, 470 b, 471 b**) can be performed with fascia placed on the malleus head and incus body, which will provide an open atticotomy and may lead to a stable situation, because the incus body and malleus prevent further retraction, and the mastoid cavity can be ventilated through the tympanic isthmus and the anterior attic, medial to the ossicles. Ventilation of the cavity lateral to the ossicles does not take place in ears with a missing bridge.

The lateral wall of the attic may be strengthened with slices or palisades of cartilage placed under the fascia.

In ears with no ossicles in the attic and no bridge (Fig. **477**), the risk of retraction into the empty attic is great, and a firm covering is necessary, either with a piece of catilage or cortical bone. One rectangular piece of tragal cartilage adapted to the remnants of the bridge (Fig. **478**) may be a solution, and one or two small pieces of cortical bone can also cover the atticotomy superior to the defective bridge. However, there will still be a weak point, with a high risk of retraction, between the pars tensa and the lower edge of the bone or cartilage. Retraction usually occurs at this point and not in the atticotomy region.

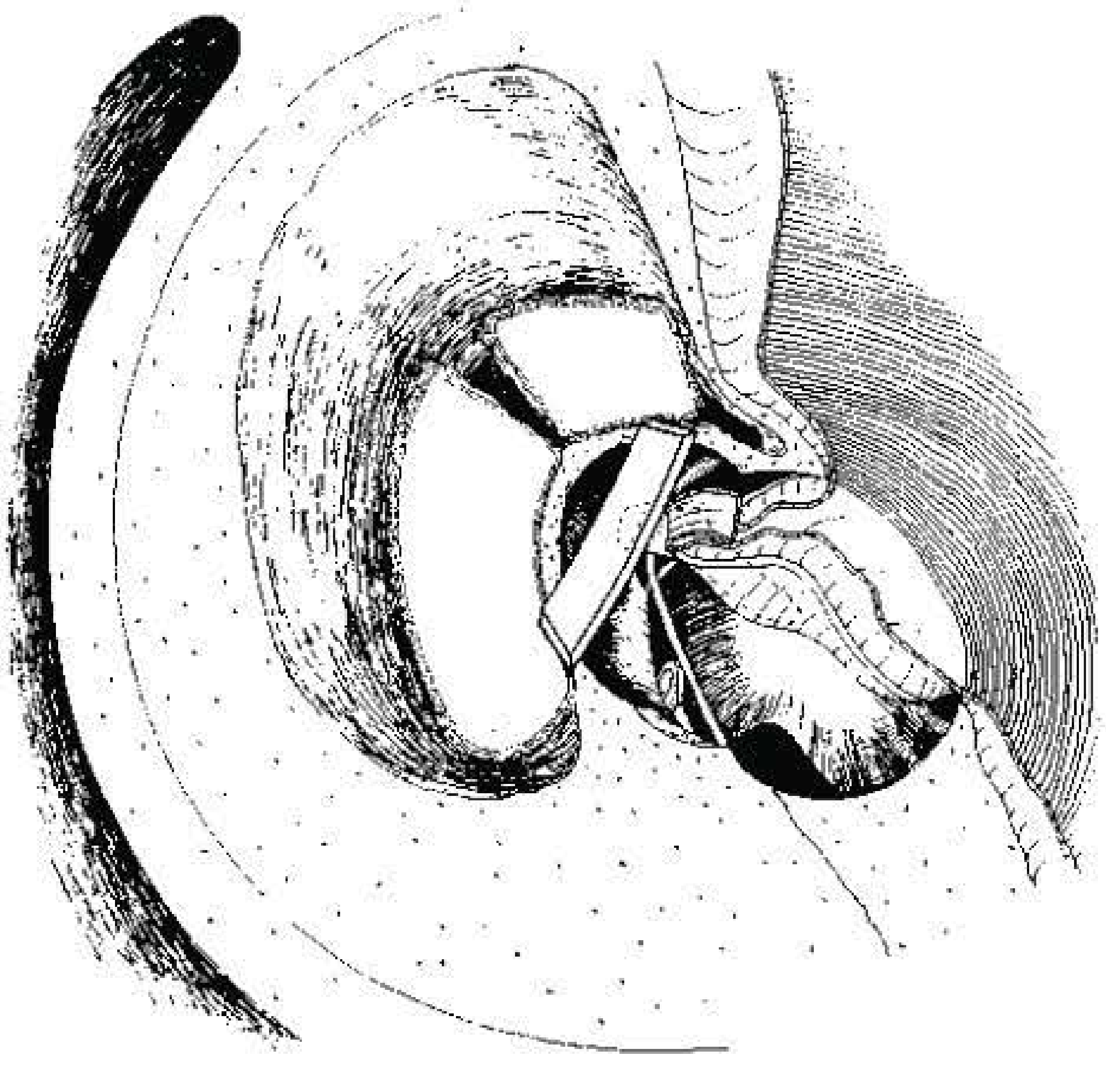


Fig. **476** **Reconstruction of the lateral attic wall after atticotomy, with superolateral displacement of the bridge.** The atticotomy opening is covered with two pieces of thin bone, with a fissure in between, to allow inspection of the attic. Inferior to the bridge, a palisade of cartilage is placed, in contact with the resected area of the malleus neck

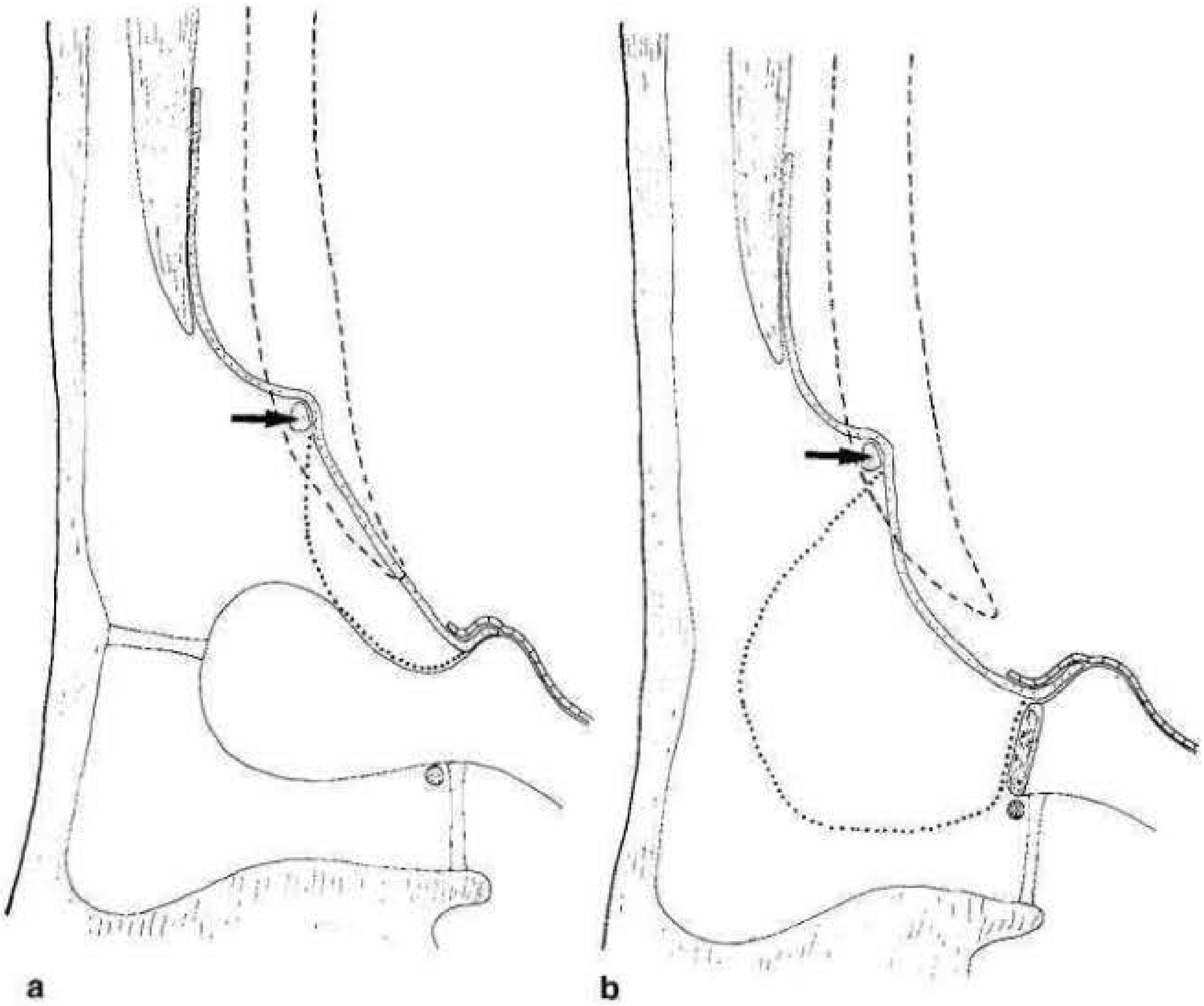


Fig. **477** Considerable superolateral displacement of the bridge (arrows) and displacement of the bony ear canal in relation to its original position (dashed lines) in cases with huge spontaneous resorption and atticotomy. The atticotomy and the open attic are covered with fascia. **a** The malleus head is present. The possibly retracted fascia will adhere the malleus head, and this may result in a stable situation (dotted line). **b** Without the malleus head. The retraction may become deep. If the bridge is resorbed, a large, safe, open attic may be the result in situations **a** and **b**

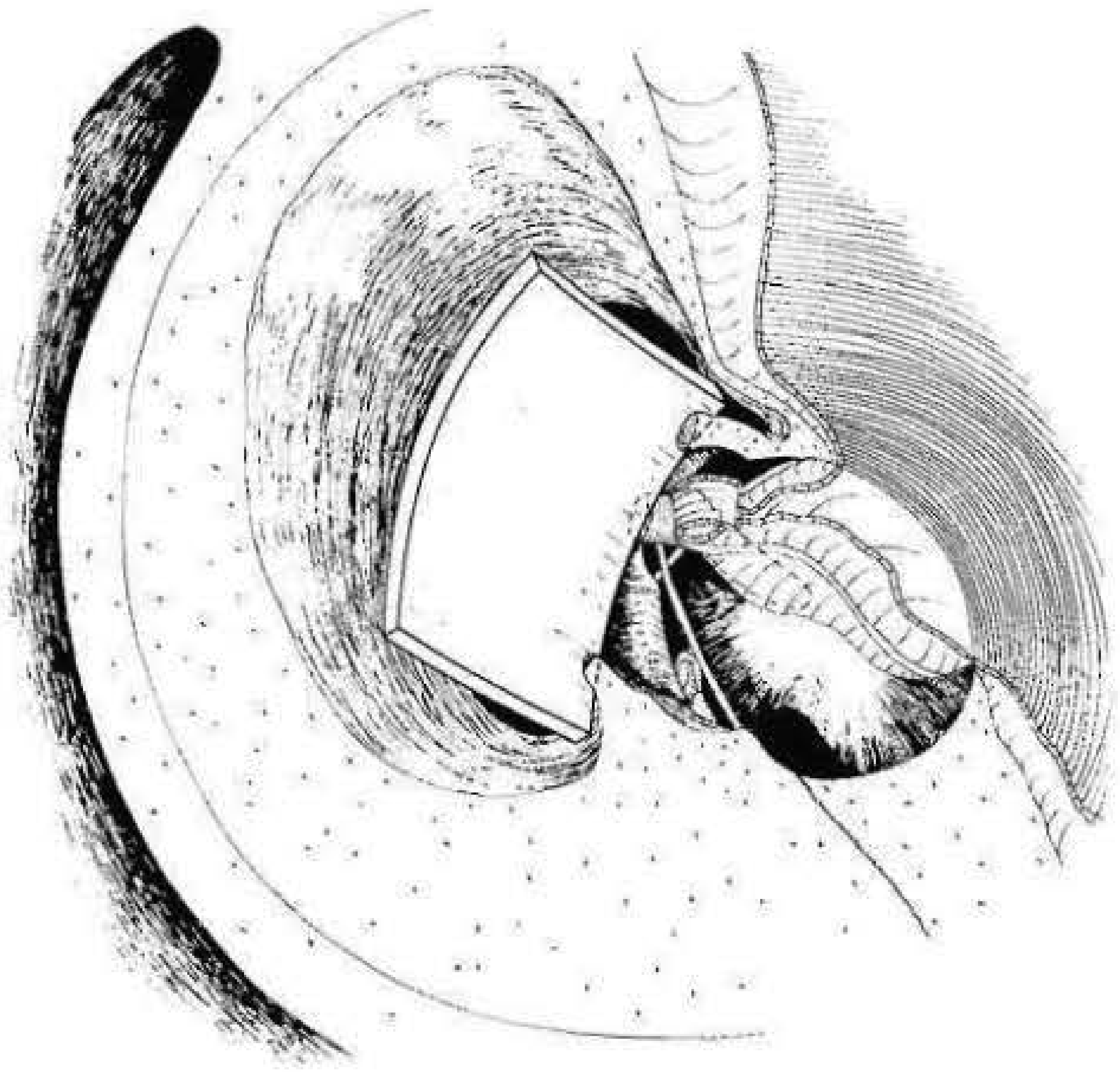


Fig. **478** **Covering the atticotomy with missing bridge** and the empty attic with a rectangular piece of tragal cartilage adapted in size to the remnants of the bridge. The cartilage is placed in contact with the neck of the malleus, and is covered with fascia

There are several other methods of covering defects of the lateral attic wall. They have already been described in reconstruction of the scutum after classic intact canal wall mastoidectomy, and can of course also be applied in modified canal wall–up mastoidectomy.

Removal of Sinus Cholesteatoma

Sinus cholesteatoma is defined as a posterosuperior retraction (of perforation) of the pars tensa with cholesteatoma membrane extending around the stapes, into the sinus tympani, and usually resorbing the stapes crura. The cholesteatoma membrane covers the walls of the sinuses — the lateral tympanic sinus, the facial sinus, the posterior tympanic sinus and the sinus tympani — and the prominence of the horizontal part of the facial nerve. Anteriorly, it extends under the malleus handle towards the tendon of the tensor tympani muscle. Progression of sinus cholesteatoma usually occurs medial to the incus (Fig. **479**) into the attic and aditus ad antrum, and from there into the antrum. The cholesteatoma does not extend to the attic through the facial recess, but covers the two lateral and two medial sinuses (Fig. **90**). In contrast to attic cholesteatoma, there is usually no extension of sinus cholesteatoma into the lateral or anterior attic or into the Shrapnell's membrane region. The surgical technique for sinus cholesteatoma is therefore different from that for attic cholesteatoma, and the author's modified intact canal wall mastoidectomy takes these differences into consideration.

Surgery for sinus cholesteatoma starts with an endaural approach using an ear speculum. A medial, posterior circumferential incision between the 12-o'clock and 6-o'clock positions, as in posterior tympanotomy, is performed. The incision permits later change to a retroauricular approach if it becomes necessary to perform an atticotomy and modified intact canal wall mastoidectomy as shown in Fig. **390.** Initially, all the work is carried out in the tympanic cavity. The posterior tympanomeatal flap is elevated and cut with a medial radial incision at the 9-o'clock position resulting in a superior and an inferior skin flap (Fig. **480**). The extent of the cholesteatoma membrane is carefully inspected, and followed around the chorda tympani into the facial sinus and the lateral tympanic sinus by elevating the chorda together with the cholesteatoma membrane. The cholesteatoma membrane is then followed inferior to the chorda, and elevated from the posterior tympanic wall and the round window niche.

Otosclerosis drilling with removal of the posterosuperior bony annulus is an important step in the surgery of sinus cholesteatoma, providing a good view of the sinuses, stapes region, and the horizontal part of the facial nerve, as well as allowing safe and precise elevation of the cholesteatoma membrane (Fig. **480**).

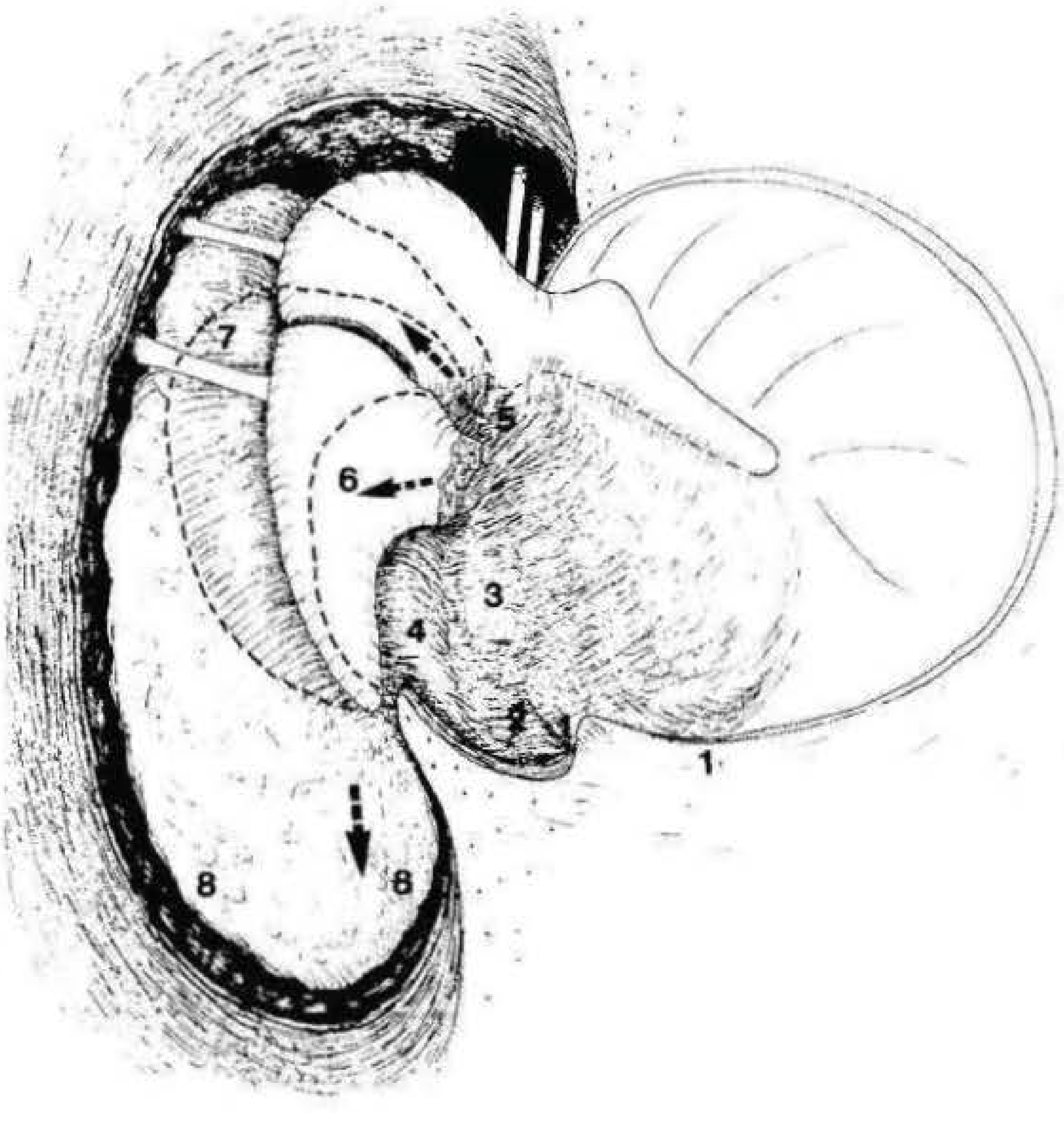


Fig. **479** **Common extension of sinus cholesteatoma,** illustrated in a large atticotympanotomy situation. A large otosclerosis drilling is performed, and the lateral wall of the attic and aditus ad antrum is removed, exposing the ossicular chain. Posterosuperiorly, the pars tensa retraction goes down into the sinus tympani, resorbing the long process of the incus and stapes crura and covering 1) the walls of the lateral tympanic sinus; 2) the pyramidal eminence and the facial sinus; 3) the footplate; 4) the eminence of the horizontal part of the facial nerve; and 5) the cochleariform process at the tendon of the tensor tympani muscle. From the mesotympanum, the cholesteatoma extends 6) under the incus through the tympanic isthmus; 7) up into the medial attic, under the superior malleolar incudal ligament; and 8) further up to the superior wall of the attic and toward the antrum. The sinus cholesteatoma does not extend into the anterior part of the cavum tympani

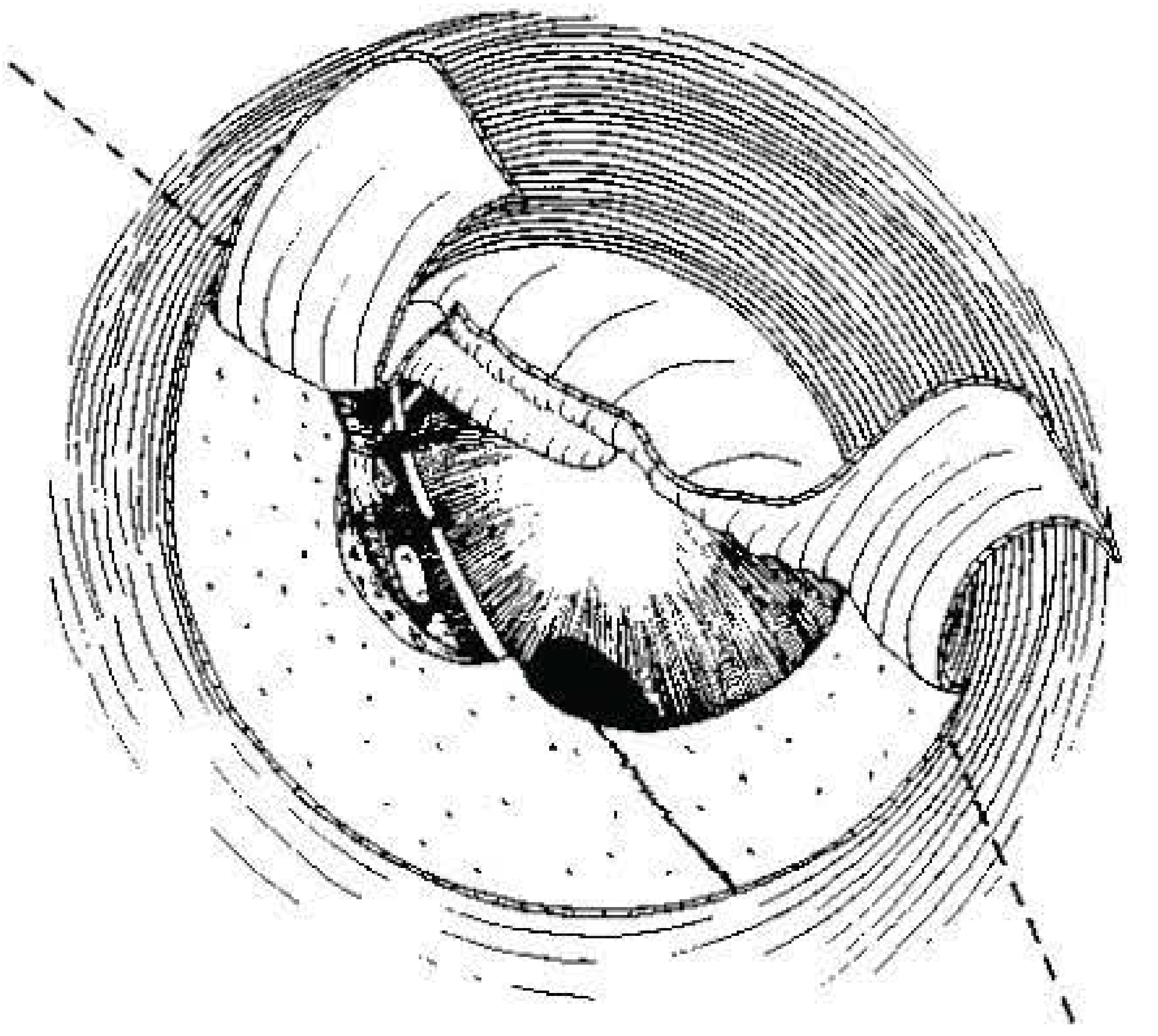


Fig. **480** **Endaural removal of sinus cholesteatoma.** A large tympanomeatal flap is elevated and cut at the 9-o'clock position, creating a superior and inferior flap. After otosclerosis drilling, the posterior tympanum and the tympanic sinuses are cleaned of cholesteatoma. The cholesteatoma membrane continues under the incus, through the tympanic isthmus, to the epitympanum (arrows). The long process of the incus is defective. The radial incisions at the 12-o'clock and 5-o'clock positions are indicated by dashed lines

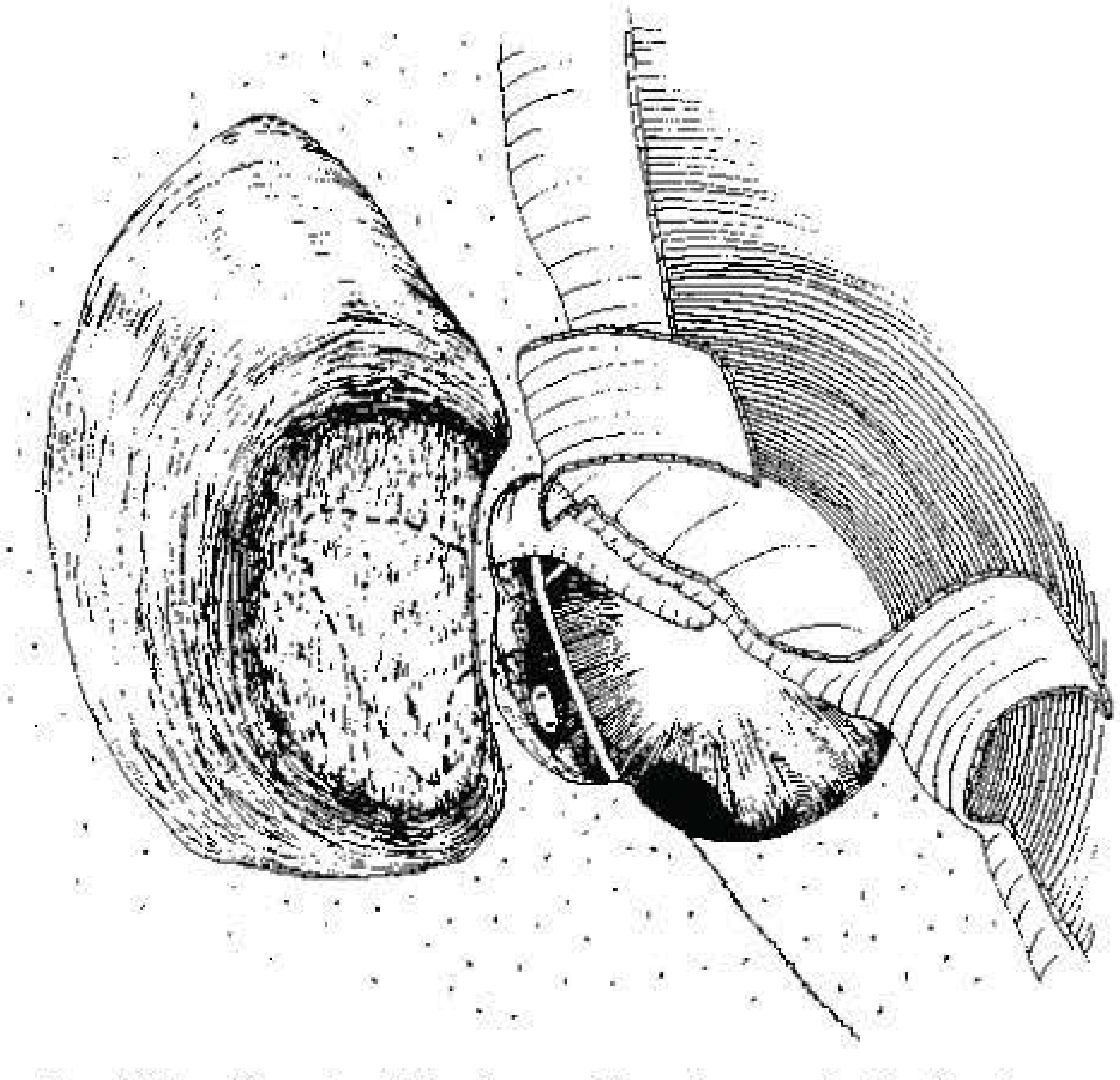


Fig. **481** **Small atticotomy in sinus cholesteatoma.** The ear canal at the tympanosquamous suture is drilled toward the bony bridge, and a small bony plateau at the lateral attic wall is created. The dashed line indicates the position of the incus and malleus

In our series, one-third of sinus cholesteatomas and tensa retraction cholesteatomas can be removed without mastoidectomy through an endaural approach with an ear speculum. These techniques will be described in Volume 3.

If the cholesteatoma membrane extends from the facial nerve prominence medial to the incus body and up to the attic or aditus ad antrum, and if it cannot be followed and safely removed by further extension of the otosclerosis drilling (Fig. **480**), a modified intact canal wall mastoidectomy is performed along lines similar to those described earlier. A postauricular approach is used (Figs. **387–395**). The atticotomy drilling in the posterosuperior ear canal wall starts somewhat posterior to the drilling used for attic cholesteatoma (Fig. **481**). The bone lateral to the bridge, at the level of incus body, is thinned to a plateau, but it is not necessary to remove the bone superior to the ShrapnelPs membrane region; since cholesteatoma is not expected to be present in the lateral and anterior attic. After removal of the bony plateau lateral to the incus body, using the same principles as described previously (Figs. **394–396**), the attic is opened, and the lateral surface of the incus body becomes visible (Fig. **482**). In cases of sinus cholesteatoma protruding medial to the incus body, the incus is extracted, and the cholesteatoma membrane is carefully elevated from the lateral semicircular canal (Fig. **483**) and removed (Fig. **484**). In cases of extension of the cholesteatoma under the malleus head, the atticotomy opening is extended anteriorly, and the head of the malleus is resected and removed together with the cholesteatoma membrane.

In most cases requiring an atticotomy, a small modified intact canal wall mastoidectomy is also performed (Figs. **408–412**), with thinning of the bony ear canal wall (Fig. **485**).

Posterior atticotympanotomy is not necessary in most cases of sinus cholesteatoma, because the cholesteatoma has already been removed from the lateral tympanic sinus and the facial sinus in the initial stages of the operation, performed using the endaural approach with a posterior tympanotomy and otosclerosis drilling. If a posterior atticotympanotomy is required, it can be performed easily, because the incus has already been removed and the incudal fossa exposed (Fig. **486**). The posterior buttress is not preserved. Because of the otosclerosis drilling with the removal of some of the posterosuperior bony annulus, the opening to the tympanic cavity will be large (Fig. **487**), and the medial route for posterior atticotympanotomy (Fig. **282**), close to the facial nerve, therefore has to be used.

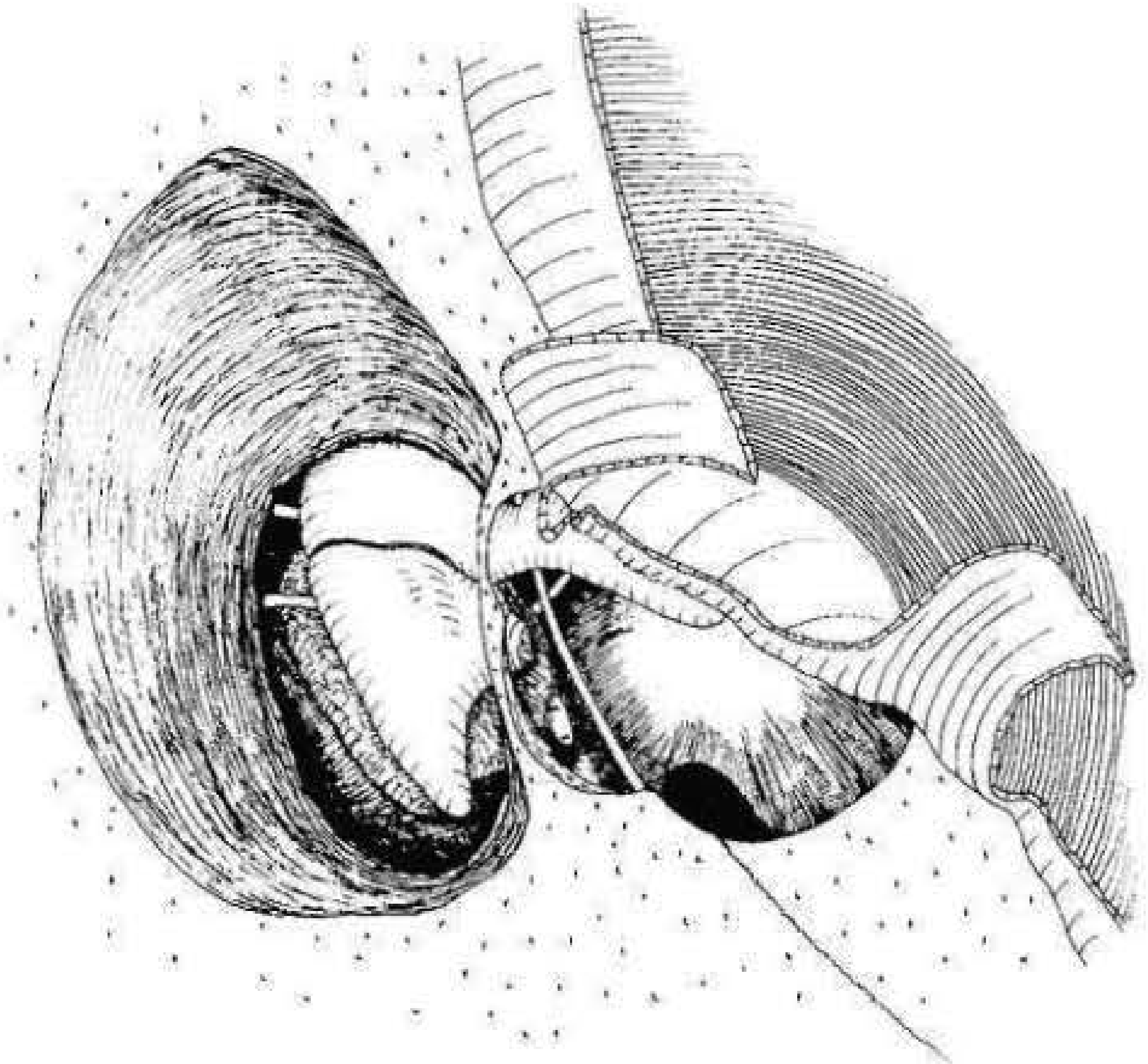


Fig. **482** A transmeatal atticotomy is performed, and the bony bridge is preserved. There is no cholesteatoma in the anterior attic, and the atticotomy therefore does not extend toward the anterior attic. The cholesteatoma protrudes into the attic, medial to the incus body

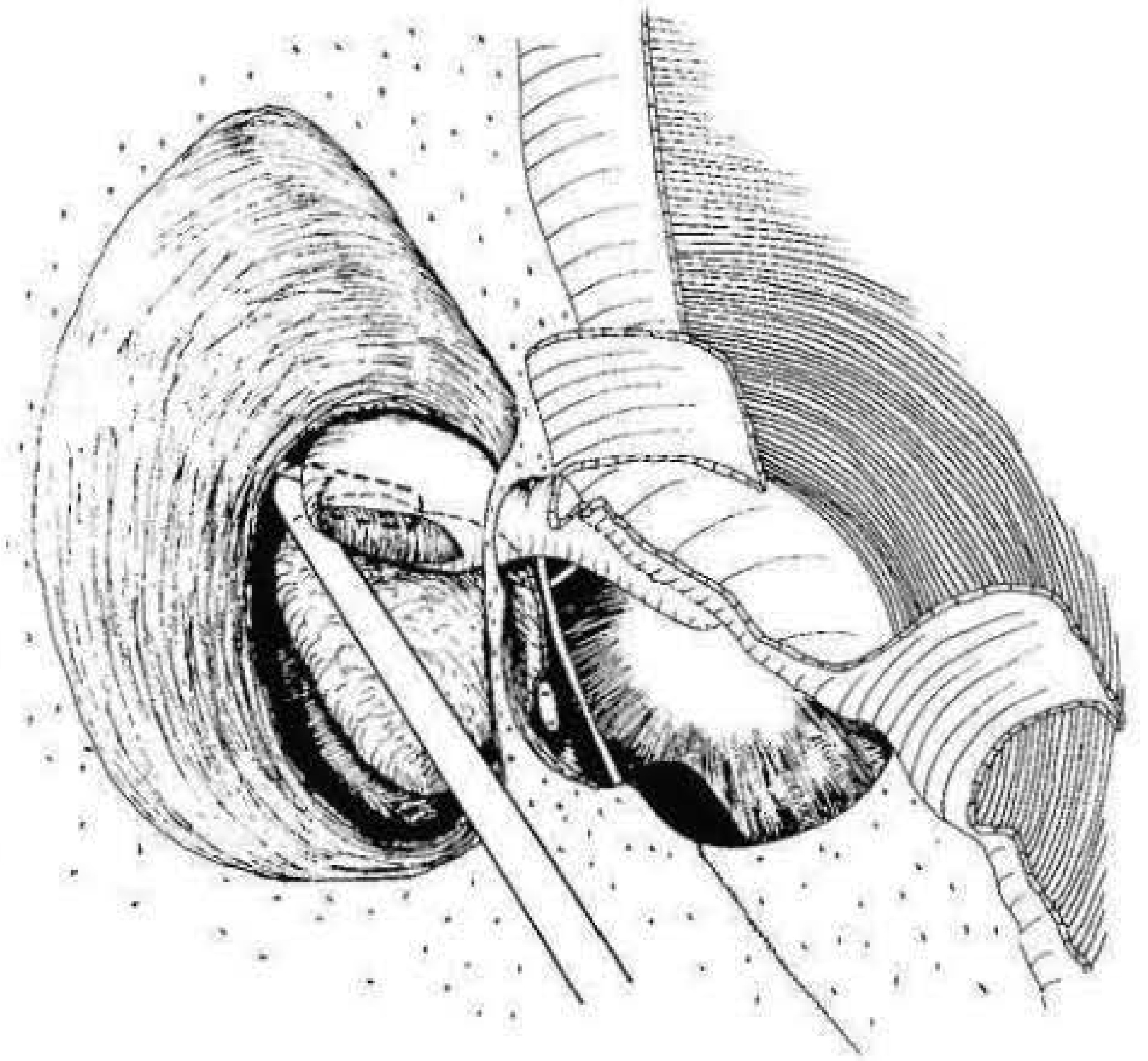


Fig. **483** The incus is disarticulated from the malleus, and the cholesteatoma membrane is elevated under the malleus head using a curved elevator

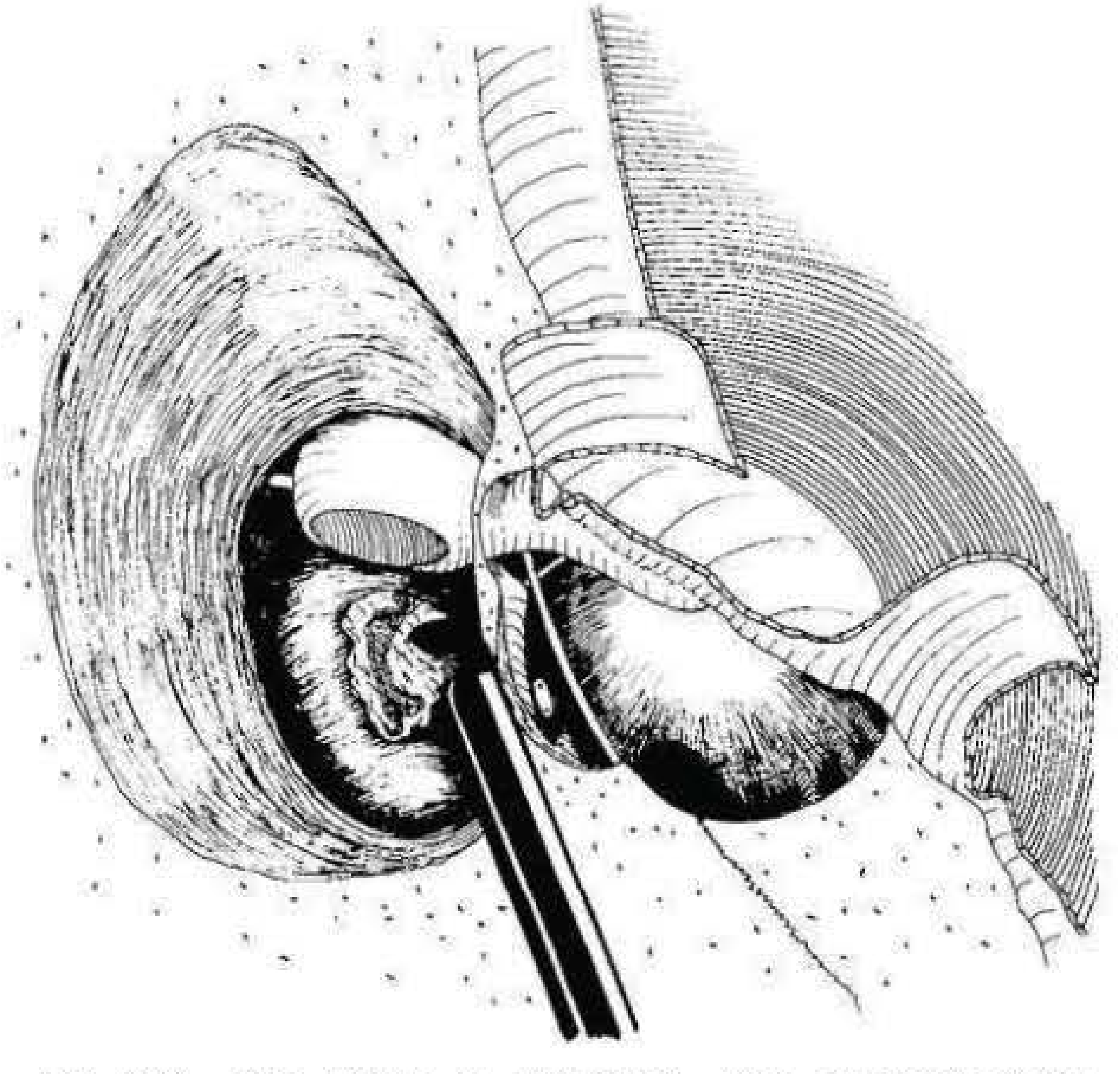


Fig. **484** The incus is removed. The cholesteatoma membrane, covering the lateral semicircular canal, is elevated and removed. The malleus head is left in place

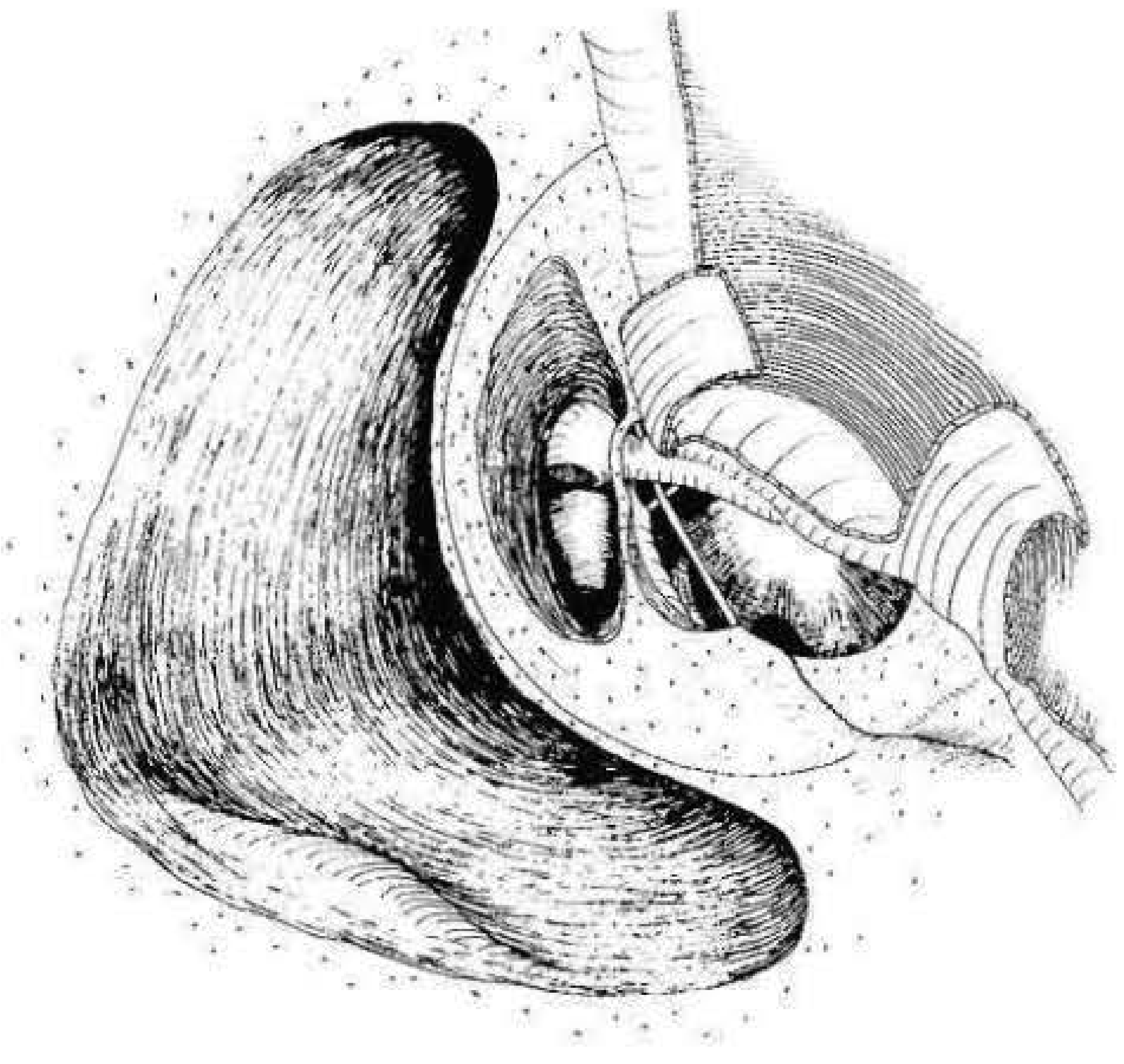


Fig. **485** **Intact canal wall mastoidectomy.** The ear canal is thinned, and the lateral semicircular canal is exposed and inspected. The mastoidectomy does not extend as far anteriorly as in attic cholesteatoma

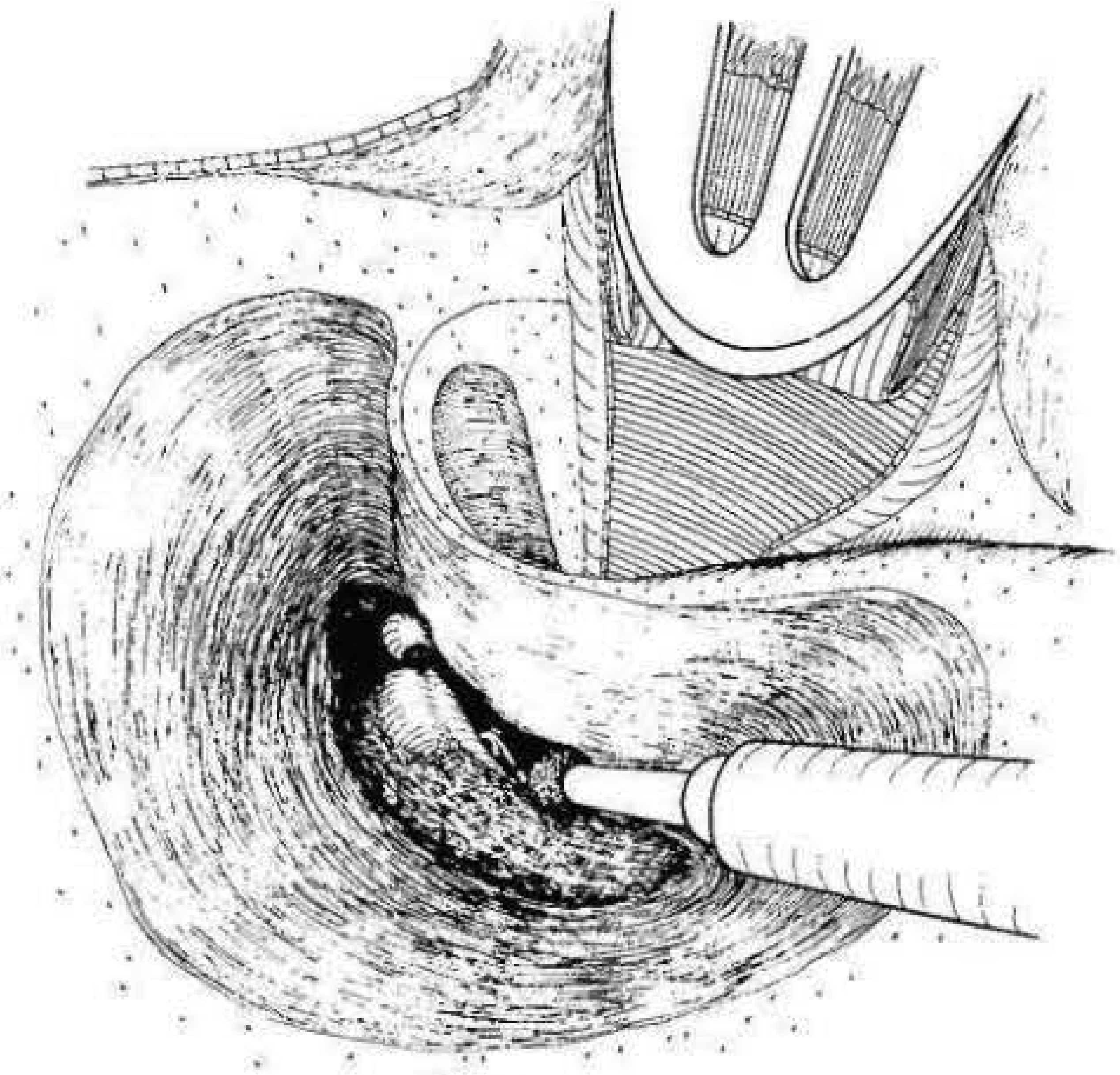


Fig. **486** **Posterior atticotympanotomy, modified intact canal wall mastoidectomy and atticotomy** in a situation with a missing incus, carried out by drilling the bone of the facial recess with a diamond burr. The stapes is visible through the atticotympanotomy

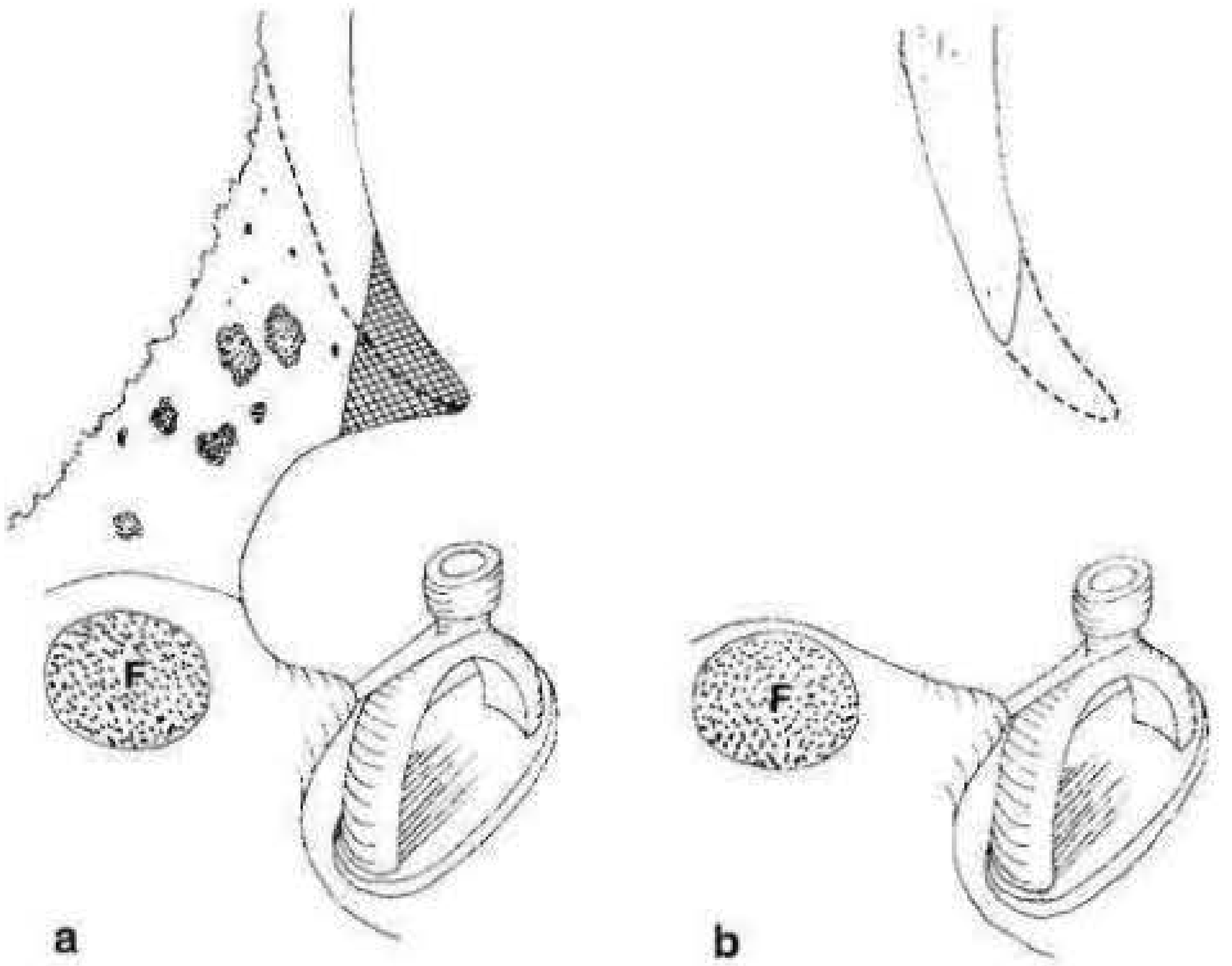


Fig. **487** **Side view of the facial recess and bone removal** in: **a** endaural otosclerosis drilling (shaded area), and **b** after atticotympanotomy. The dotted area indicates the position of the posterior bony annulus in classic intact canal wall mastoidectomy. F: facial nerve

Reconstruction in Cases of Sinus Cholesteatoma

The autogenous incus is used for ossiculoplasty even if it has been in contact with the cholesteatoma membrane. If there are no signs of resorption of the incus body as seen under the operating microscope, it can safely be cleaned and reused. As an alternative, the author uses cortical bone. The drum perforation is closed with an underlay fascia graft.

The atticotomy opening can be closed with fascia done, or with a piece of cartilage or bone, as illustrated previously (Figs. **462–464**).

In sinus cholesteatoma, spontaneous resorption of the lateral attic wall does not occur, and the bridge always remains intact; drilling far anteriorly into the attic is not necessary, making the reconstruction easier and safer. Postoperative retraction does not occur at the site of the atticotomy, but in the posterosuperior quadrant of the ear drum, i. e., in exactly at the same place as the original retraction.

The goal of reconstruction is to provide ventilation to the posterior tympanum and prevent the formation of adhesions between the promontory and the drum. This can be achieved by placing small pieces of thin Silastic onto the promontory and a grommet in the anterosuperior quadrant of the drum, or by using a relatively large ossicle as a type II or type III ossiculoplasty, placed in such a way that it prevents retraction of the posterosuperior part of the eardrum. Gelfoam within the tympanic cavity is avoided, if possible.

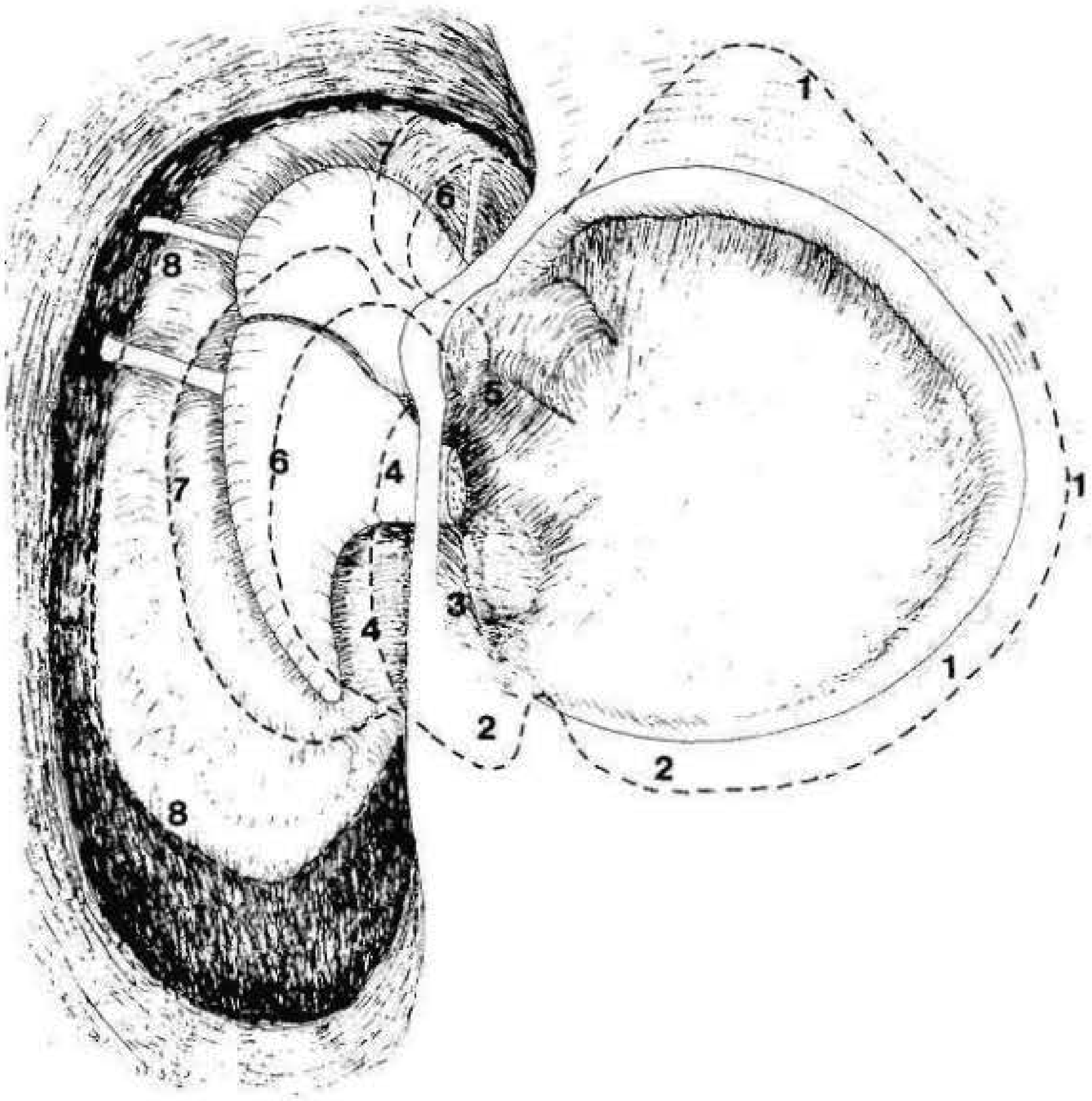
Removal of Tensa Retraction Cholesteatoma

In cases of tensa retraction cholesteatoma, the entire pars tensa is retracted and adherent to the medial wall of the tympanic cavity. Posterosuperiorly, the retraction is similar to that in sinus cholesteatoma (Fig. **479**). Inferiorly, the retraction passes around the fibrous annulus and continues medially, covering the walls of the hypotympanum. Anteriorly, the retraction covers the lateral wall of the tympanic orifice of the Eustachian tube, and from the promontory the cholesteatoma membrane extends into the tympanic orifice of the Eustachian tube, covering its medial wall (Fig. **488**). Anterosuperiorly, the cholesteatoma extends, under the anterior maleus fold, into the anterior attic. It passes under the remnant of the malleus handle up to the tendon of the tensor tympani muscle.

The modified intact canal wall mastoidectomy is performed according to the same principles as in sinus cholesteatoma, but the work in the tympanic cavity is much more extensive.

In our series, one-third of cases of tensa retraction cholesteatomas are removed by tympanoplasty

Fig. **488** **Extension of tensa retraction cholesteatoma,** illustrated in a situation with a large atticotomy. The cholesteatoma membrane covers the entire medial wall of the tympanic cavity, and goes 1) around the annulus covering the walls of the tympanic cavity, the posterior tympanum, the tympanic sinuses, and anterior tympanum, extending to the tympanic orifice of the Eustachian tube. The malleus handle is resorbed. The cholesteatoma covers 2) the lateral tympanic sinus and the facial sinus; 3) the prominence of the horizontal part of the facial nerve; 4) extends up under the incus along the tympanic isthmus toward the epitympanum; and 5) posteriorly surrounds the tendon of the tensor tympani muscle. The cholesteatoma extends under the malleus head and incus body toward the attic (6, 7) and toward the antrum (8)



only; in the other two-thirds, mastoidectomy is performed, usually with a canal wall–down procedure.

When performed for tensa retraction cholesteatoma, the modified intact canal wall mastoidectomy. Continues with an atticotomy with a retroauricular approach after endaural cleansing of the tympanic cavity with otosclerosis drilling. The atticotomy extends to the anterior and posterior attic. Usually, the long process of the incus is missing, and the incus is extracted and the malleus head resected and extracted, resulting in an empty attic and total perforation, leaving only the remnant of the malleus handle (Fig. **489**). Tubal function is poor, and the middle ear mucosa is abnormal, if present at all. The prognosis is generally poor (Lau and Tos 1989).

Reconstruction of Ears with Tensa Retraction Cholesteatoma

After placing a large, thin silastic sheet on the promontory and performing an ossiculoplasty with an autogenous incus or cortical bone, fascia is placed on the annulus and on the remnant of the malleus handle.

The atticotomy is covered with a piece of cartilage or cortical bone, and the mastoid cavity is ventilated with a tube placed into the cavity and left in place for three weeks.

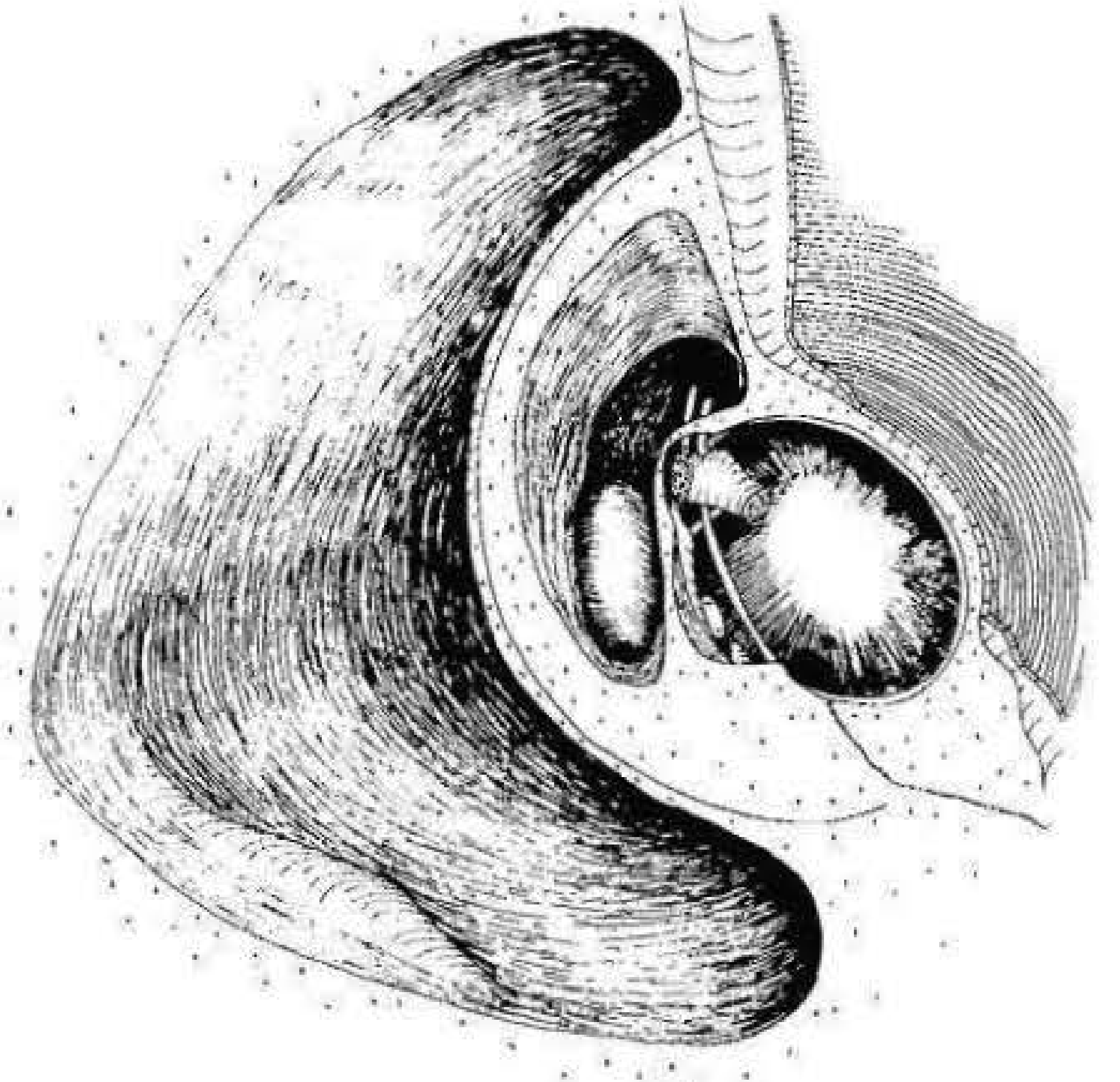


Fig. **489** **Removal of the tensa retraction cholesteatoma.** The cholesteatoma membrane from the tympanic cavity is removed, the malleus neck is cleaned, and otosclerosis drilling is performed, resulting in a total perforation. The epithelium from the lateral aspect of the annulus is removed, and the annulus is cleaned in order to place an onlay fascial graft onto the annulus. Atticotomy is performed, the malleus head is resected, the incus is removed, and an intact canal wall mastoidectomy is performed

The Philosophy of Modified Intact Canal Wall Mastoidectomy

Modified intact canal wall mastoidectomy is based on different surgical principles from those of the classic intact canal wall mastoidectomy, and on a different philosophy. It aims to create conditions in the attic such that repneumatization of the mastoid cavity can take place through the tympanic isthmus and the attic in patients with good, or even fair, tubal function. In patients with poor tubal function, conditions are created in the attic such that retraction does not necessarily lead to recurrent cholesteatoma, requiring reoperation, but most often to a stable, small cavity with a wide neck. In addition, any residual cholesteatoma can be observed through the atticotomy opening — if it is not completely covered with bone or cartilage — making a second-look operation or second-stage surgery unnecessary.

The modification of intact canal wall mastoidectomy presented here has several technical advantages in cases of **attic cholesteatoma** when compared with the classic intact canal wall mastoidectomy. Removal of cholesteatoma from the tympanic sinus is safer and easier after "otosclerosis drilling" of the posterior wall of the bony annulus. All ear surgeons have extensive experience of operating on the stapes and footplate through this direct route. This may explain why the frequency of residual cholesteatoma in our experience has been considerably lower than that published for the classic intact canal wall mastoidectomy (Tos 1982 a, Tos and Lau 1988, Tos and Lau 1989 a, Tos and Lau 1989 b, Sheehy 1970 a, 1970 b, Glasscock and Miller 1976, Abramson et al. 1977, Austin 1977, Smyth 1976, Cody and Taylor 1977, Sadé 1977, Sheehy et al. 1977, Wright 1977, Schwaber 1979). If the cholesteatoma is located between the facial nerve and the posterior crus of the stapes, or medial to the tendon of the stapedial muscle, i. e., within the posterior tympanic sinus, it cannot, in the author's opinion, be removed through a posterior atticotympanotomy.

There are no disadvantages associated with otosclerosis drilling, as the presence of the interposed ossicle between the stapes and the drum prevents posterior retraction of the pars tensa and, should retraction occur, the chances of selfcleaning are greater.

In **sinus cholesteatoma and tensa retraction cholesteatoma,** there is always pathology in the posterior tympanum, and otosclerosis drilling is very important in order to carefully dissect the cholesteatoma membrane, which may adherent to the posterior tympanum and walls of the tympanic sinuses. Meticulous dissection in the posterior tympanum can only be performed through the transcanal route. Through a posterior atticotympanotomy, even if it is maximally extended, such dissection is very difficult, and the risk of residual cholesteatoma in the posterior tympanum is much greater in the classic rather than in the author's modified intact canal wall technique (Lau and Tos 1988 a, 1988 b).

Atticotomy provides an opportunity for a direct survey of the anterior attic, this being the second most frequent location for residual cholesteatoma, and it permits early removal of the cholesteatoma membrane from the anterior attic and around the anterior part of the chorda tympani. When attempting to remove the cholesteatoma from the anterior attic through the mastoidectomy, it is necessary to perform extensive drilling and to create a large cortical mastoidectomy posterior to the sigmoid sinus. Such extensive removal of healthy bone is avoided when the cholesteatoma has been removed through the atticotomy, and only a small mastoidectomy is required in order to remove the cholesteatoma, which extends to the aditus ad antrum. To make the mastoidectomy larger than necessary creates unfavorable conditions, with the possibility of a retraction pocket and also possible repeat surgery at a later stage. Another considerable advantage of atticotomy covered by fascia is the opportunity it provides to look into the attic after the operation, excluding the presence of any residual cholesteatoma and at the same time establishing whether there is air behind the atticotomy membrane. In this way, a second-look operation can also be avoided. The disadvantage of an atticotomy is that a new weakness is created in the attic wall where a retraction may occur. Analysis of our material (Tos 1982 a) showed, however, that in cases with an intact bridge, the retraction appeared between the bridge and the pars tensa, but not at the site of the atticotomy. In cases with considerable spontaneous erosion of the attic wall and without an intact bridge, the retraction appeared at the site of the bridge defect. As soon as a retraction pocket has begun to develop, the atticotomy becomes advantageous, as the retraction increases fairly quickly, the bridge is resorbed, and the result is an open cavity with a wide neck that can be cleaned. Usually, the retraction develops into a selfcleaning cavity. Covering spontaneous erosion with bone or cartilage does not, in our series, prevent retraction any more than covering it with fascia, nor are the functional results better (Tos 1982 a).

In sinus cholesteatoma, atticotomy of the anterior attic is less important, as there is usually no cholesteatoma at that site, and the atticotomy therefore does not need to extend as far anteriorly; however, it is necessary for it to extend posteriorly (Fig. **481**). With further extension in a posterior direction, the atticotomy can be termed aditotomy, because the aditus ad antrum is opened. In many cases with sinus cholesteatoma, the cholesteatoma can be safely removed with atticotomy alone. In large sinus cholesteatoma extending into the antrum, posterior atticotympanotomy can be performed, but if the transmeatal cleaning of the sinuses has been efficient, atticotympanotomy is usually not necessary.

In tensa retraction cholesteatoma, the main problems are located in the tympanic cavity, and again otosclerosis drilling is an important step in cleaning the posterior tympanum. Cleaning of the anterior tympanum as far as the tympanic orifice of the Eustachian tube is, however, easier from the retroauricular approach.

It has often been claimed (Gibb 1977) that the intact ossicular chain should be disrupted when performing a canal wall–up mastoidectomy and posterior atticotympanotomy. The author has hardly ever disconnected an intact chain, and the results have proved to be more favorable with an intact chain (Tos 1982 a, Tos and Lau 1989 c, Tos and Lau 1991). Results are also good with canal wall–down mastoidectomy, and in cases where cleaning of the incus body and malleus handle is not possible, the canal wall–down technique or atticoantrotomy are therefore preferable, leaving the cholesteatoma matrix on the ossicles (Baron 1949, 1967, 1969).

Many surgeons have abandoned the classic intact canal wall mastoidectomy method because of the need for second-look and two-stage operations, which the method ostensibly requires (Smyth 1976, Cody and Taylor 1977). The author has not performed two-stage operations, and does not support the reputation that the classic intact canal wall technique has for providing repneumatization, even when all pathological features, including poor tubal function, suggest that it will not remain stable in the long run. The philosophy behind the author's present modification of combined-approach tympanoplasty has been to give patients a chance of repneumatization and at the same time to create conditions in the attic such that failed repneumatization and subsequent retraction do not necessarily lead to recurrent cholesteatoma and repeat surgery, but to an open cavity. Repeat surgery for retraction in the attic almost always involves a conservative radical operation with an open cavity, but it is just as well to postpone reoperation and see if a cavity develops spontaneously.

8 Temporary Displacement or Removal of the Bony Ear Canal Wall

After intact canal wall mastoidectomy was introduced, it became obvious that, in some situations, certain regions of the tympanic cavity are inaccessible if the bony ear canal is preserved. Therefore, by the early 1960s, efforts were being made to displace or remove the bony ear canal during surgery and then replace it after completing the cholesteatoma removal.

Several methods incorporating temporary removal of the bony ear canal have been recommended and applied. During the evolution of the procedure the following points varied: 1) the method of removal or replacement of the ear canal; 2) the extent of the ear canal wall to be removed and replaced; and 3) the methods of fixation of the replaced ear canal wall.

Schnee (1963, 1964, 1969) was the first to apply temporary displacement of the bony ear canal wall; Lapidot and Brandow (1966), Richards (1972), and Lin (1990) also applied *mobilization and displacement* of the bony ear canal wall. Other surgeons, such as Gerlach (1969a, 1969b), Portmann (1979), S. Wullstein (1972, 1973, 1974), Feldmann (1977, 1978), Tange (1988), Babighian (1992 a, 1992b), and Mercke (1987) used *temporary removal* of the bony ear canal wall.

Temporary Displacement of the Bony Ear Canal Wall

The ear canal skin is not elevated from the bony ear canal wall or the drum. The bony ear canal wall is mobilized by osteotomies, and pushed anteriorly while still attached to the ear canal skin and possibly the drum remnant. Various techniques have been used; some surgeons elevate part of the ear canal skin transmeatally (Schnee 1963) others do not (Lapidot and Brandow 1966, Richards 1972). Some mobilize the entire ear canal wall (Schnee 1964, Richards 1972), while others only mobilize its posterior portion (Lapidot and Brandow). Some do not perform posterior atticotympanotomy (Schnee, Lapidot and Brandow), but Richards does.

Osteoplastic Mastoidectomy (Schnee)

Schnee (1963, 1964) used an endaural approach, and started the perforation work as follows:

1. Transmeatal preparation of the drum perforation by stripping the deep marginal mucosa in a small perforation, for closure with an underlay vein graft, or, in larger perforations, removal of the epithelium of the drum, for closure with an onlay fascia graft at the end of the operation (Fig. **490**).
2. Posterior tympanotomy with a relatively large circumferential incision extending from the 3-o'clock position anteriorly to the 6-o'clock position inferiorly (Fig. **490**). A large tympanomeatal flap is then elevated, exposing the entire posterior tympanum (Fig. **491**).
3. Atticotomy: The bony annulus is removed between the 9-o'clock and 1-o'clock positions, thus performing a small atticotomy, to expose the neck of the malleus, the entire long process of the

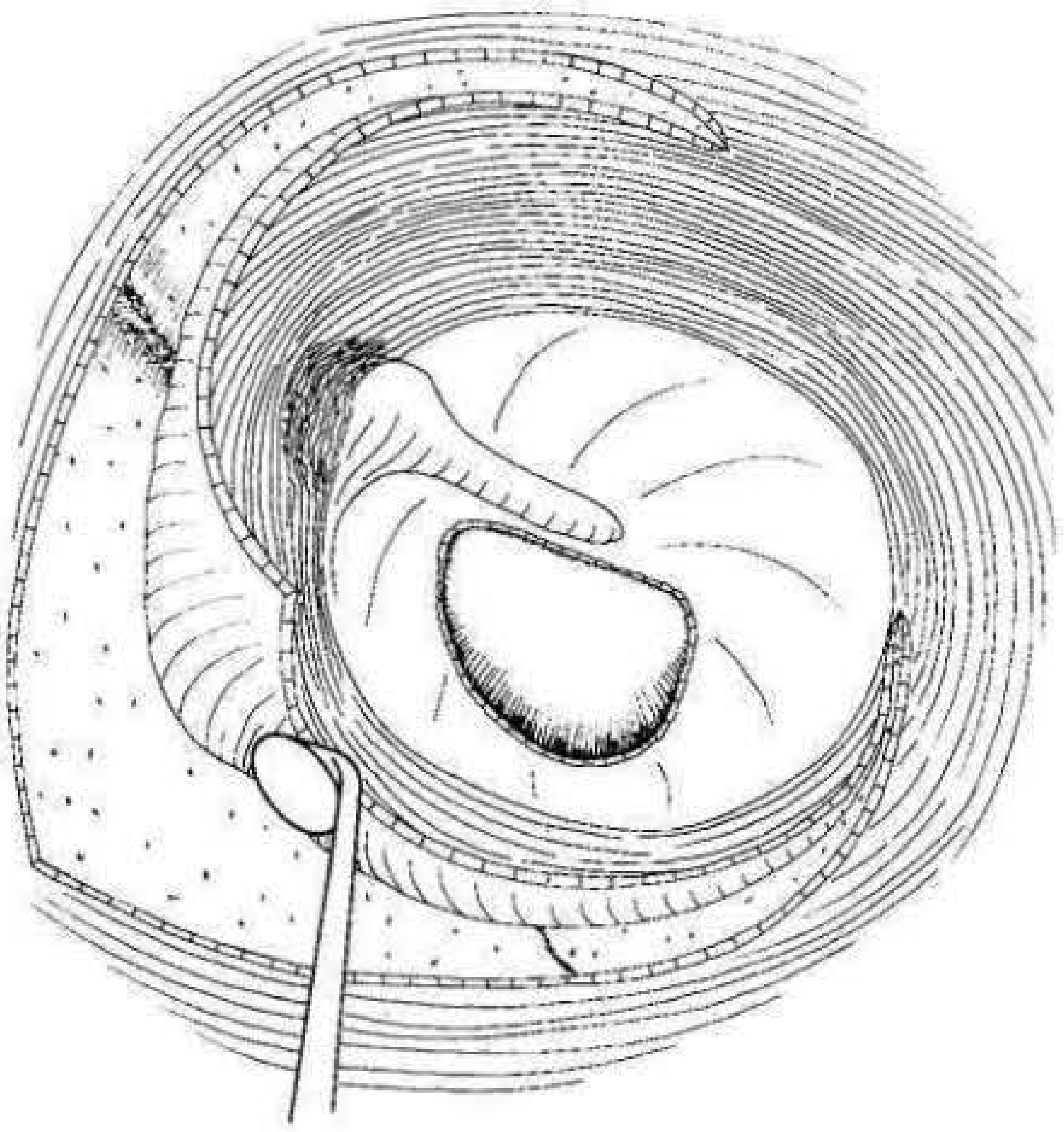


Fig. **490** **Osteoplastic mastoidectomy (Schnee).** After excising the margins of the posterior perforation to be closed at the end of the operation, a large posterosuperior circumferential incision of the ear canal skin is made incus, and the horizontal part of the facial nerve (Fig. **491**). All pathology from the tympanic cavity, mesotympanum, and as much as possible from the attic, is then removed.

4. After completing the work within the tympanic cavity, a modified Lempert endaural incision is performed for the mastoidectomy (Vol. 1, Figs. **53–57**). After a vertical incision anterior to the helix and a cirumferential incision through the ear canal skin at the entrance of the external acoustic meatus as indicated by Lempert, Schnee's modification avoids the need for two radial incisions and the elevation of the Surdille flap, allowing the ear canal skin to remain in contact with the mobile bony ear canal (Fig. **492**).
5. An extended cortical mastoidectomy is performed (Fig. **493**), and the atticotomy is completed through the mastoid route. The ear canal wall is thinned.
6. An osteoplastic flap is created by making a superior osteotomy at the level of the zygomaticomastoid junction, using a small sharp cutting burr (Fig. **494**). The drilling is continued as far as the periosteum of the ear canal, taking care not to damage or perforate the ear canal skin. An inferior osteotomy is started at the posterior buttress, lateral to the chorda tympani, which remains intact (Fig. **495**). After otosclerosis drilling and carrying out a small atticotomy at the beginning of the operation (Fig. **491**), leaving the chorda tympani exposed along its entire course through the tympanic cavity, the chorda tympani can be preserved. With further drilling, avoiding damage to the canal skin, a block of bone is created, and the canal skin remains attached to this block. By slight elevation of the periosteum above and below the osteotomies (Fig. **496**), the osteoplastic flap becomes mobile, so that it can be advanced anteriorly (Fig. **497**) or rotated slightly clockwise, if the superior part of the osteoplastic mastoidectomy requires particular visualization or exposure, e. g., in attic cholesteatoma or in tensa retraction cholesteatoma with progression into the anterior attic and tympanic orifice of the Eustachian tube. If the inferior part of the tympanic cavity has to be exposed, the osteoplastic flap is slightly rotated anticlockwise (Fig. **497**), e. g., in sinus cholesteatoma with extension into the tympanic sinuses.

The bone adjacent to the facial recess can be drilled away, both medial and lateral to the chorda tympani, under direct vision.

After the osteoplastic mastoidectomy has been completed, the bony ear canal wall is replaced in its

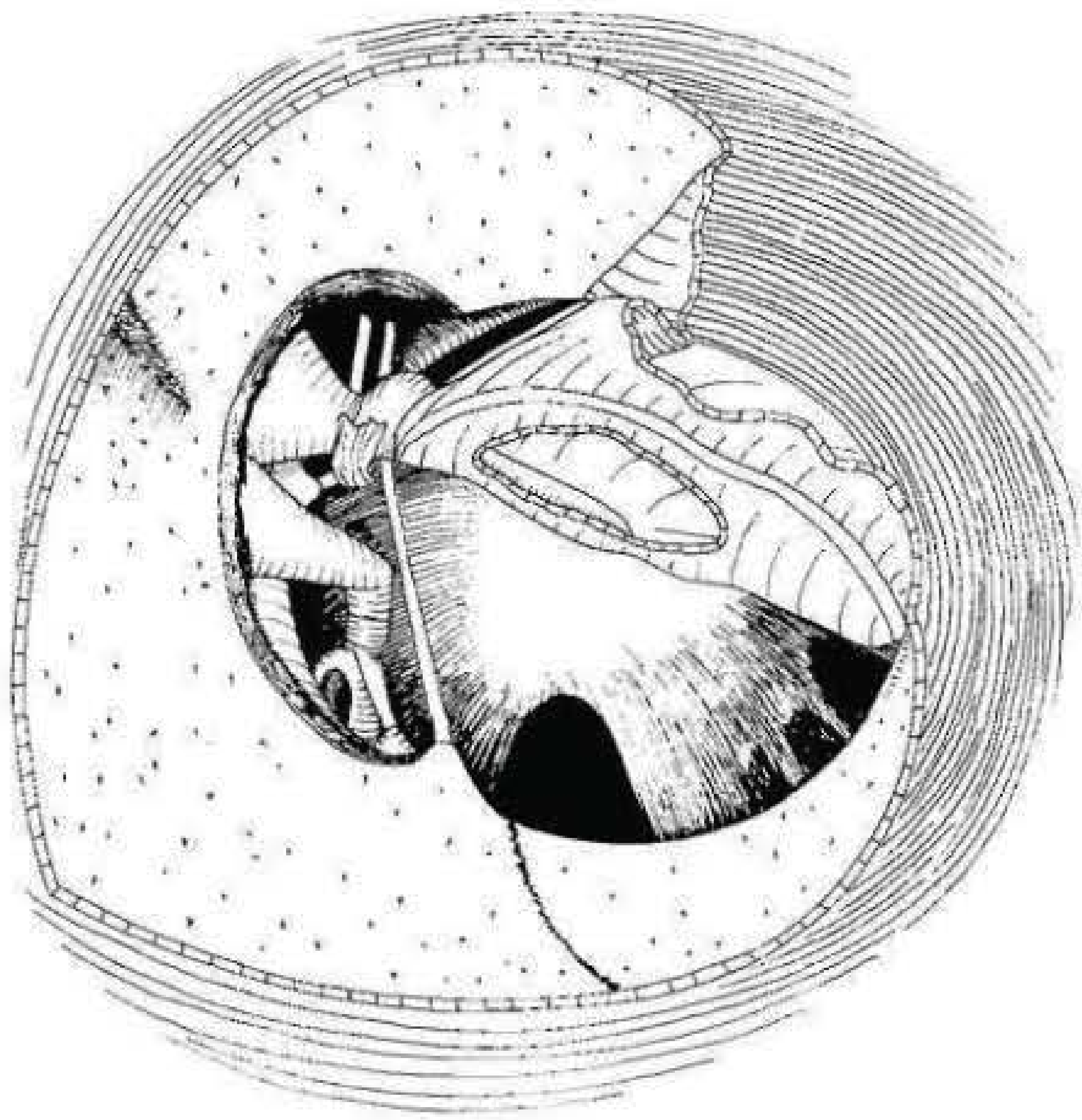


Fig. **491** The tympanomeatal flap and the fibrous annulus, including the drum remnant, are elevated, exposing the posterior half of the tympanic cavity. The elevation is continued far anteriorly, exposing the lateral wall of the attic. The bony annulus from the 9-o'clock to the 1-o'clock positions is removed by drilling with a diamond burr, exposing the horizontal part of the facial nerve, the whole of the long process of the incus, the neck of the malleus, and the anterior malleolar ligament

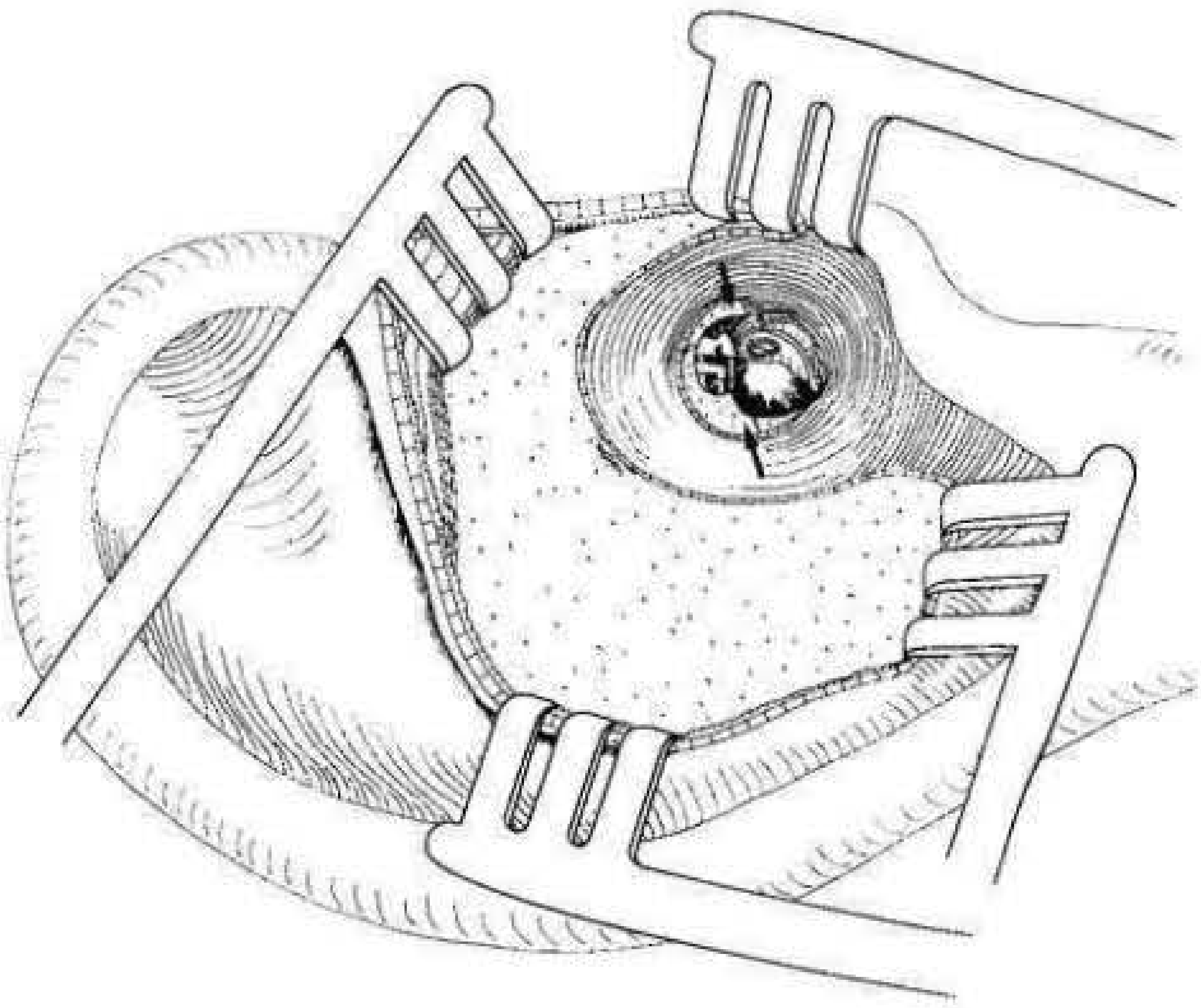


Fig. **492** A modified Lempert's endaural approach is applied with a vertical incision and a circumferential incision through the meatal skin at the entrance of the meatus, extending form the 3-o'clock to the 5-o'clock positions. The mastoid cortex is exposed, and the retracted soft tissue is held in place by four retractors. In the tympanic cavity, the denuded bone of the medial part of the ear canal is illustrated (arrows)

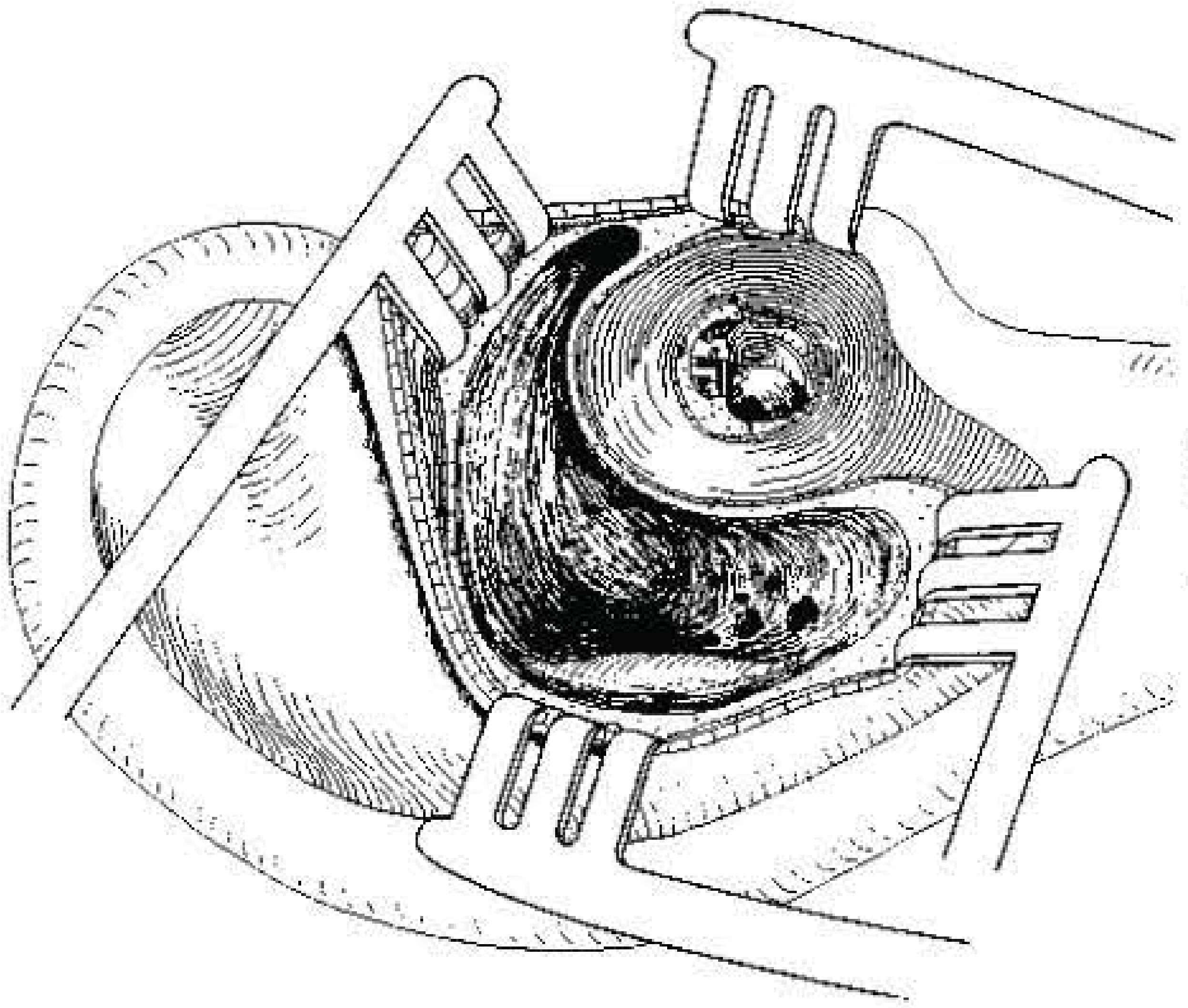


Fig. **493** Intact canal wall mastoidectomy is performed. The bony ear canal is thinned maximally all the way around as far as the anterior attic, and the ear canal skin is attached to the lateral half of the bony ear canal

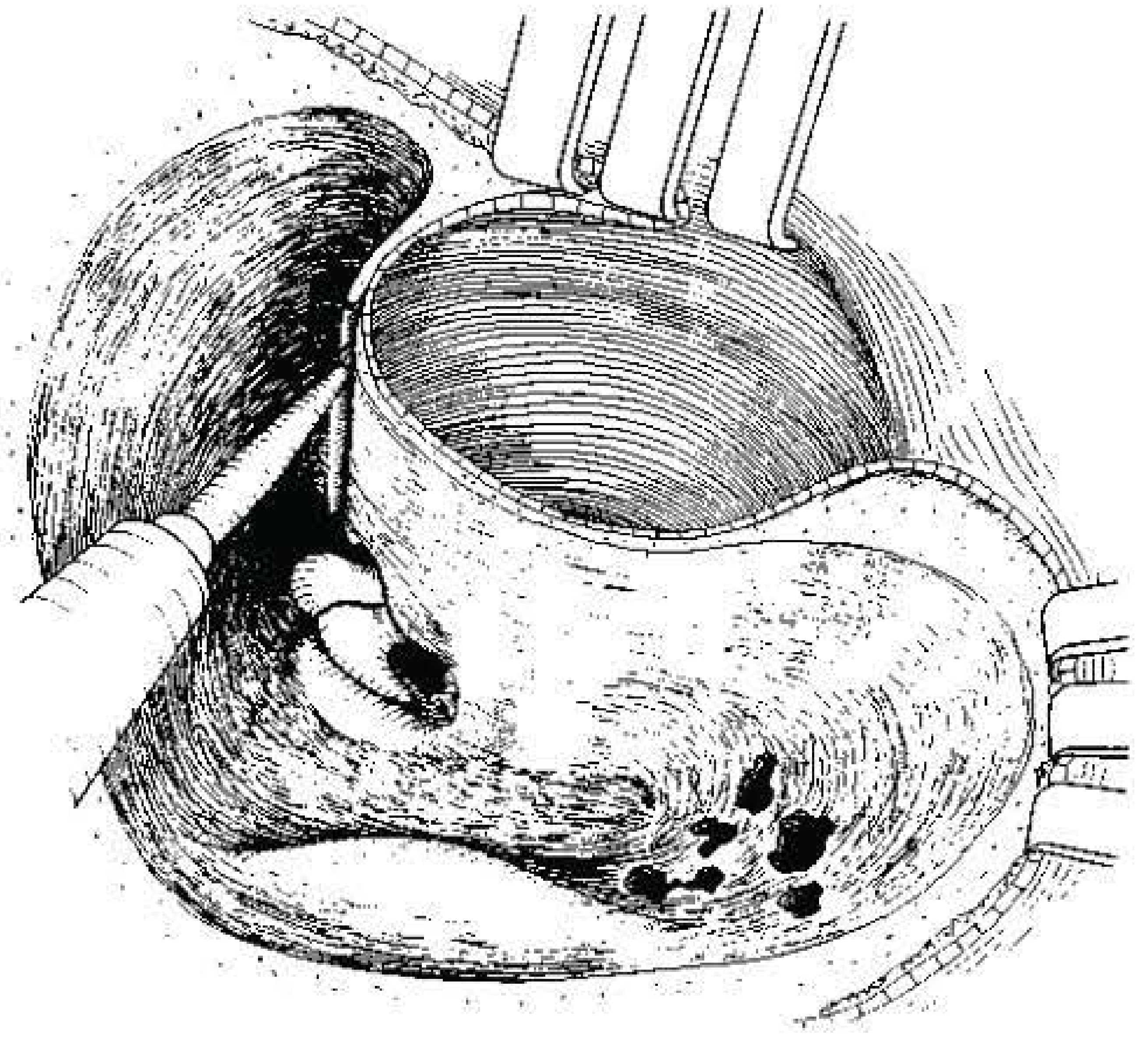


Fig. **494** A superior osteotomy is performed far anteriorly toward the zygomatic root, using a small sharp burr

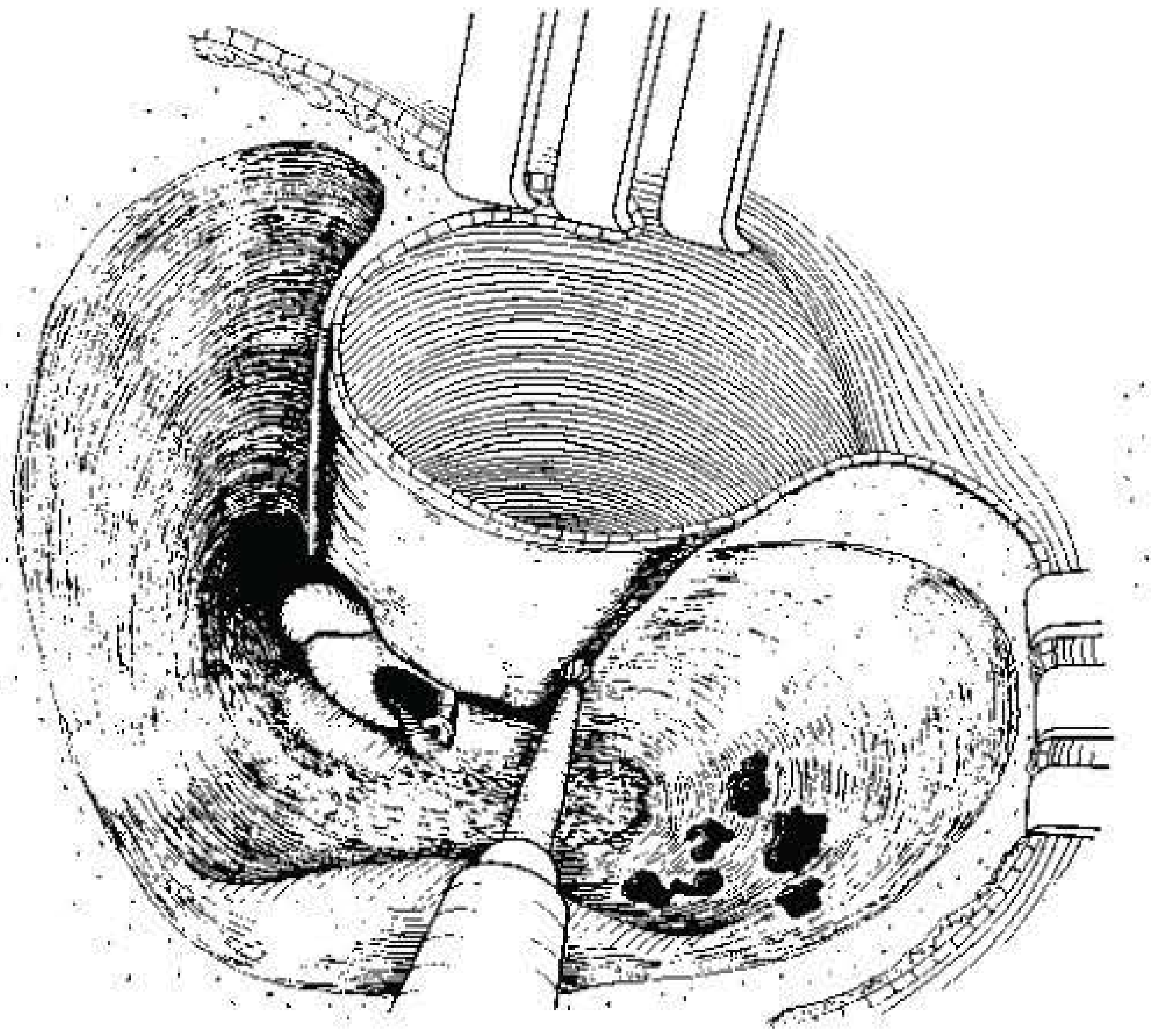


Fig. **495** An inferior osteotomy is performed

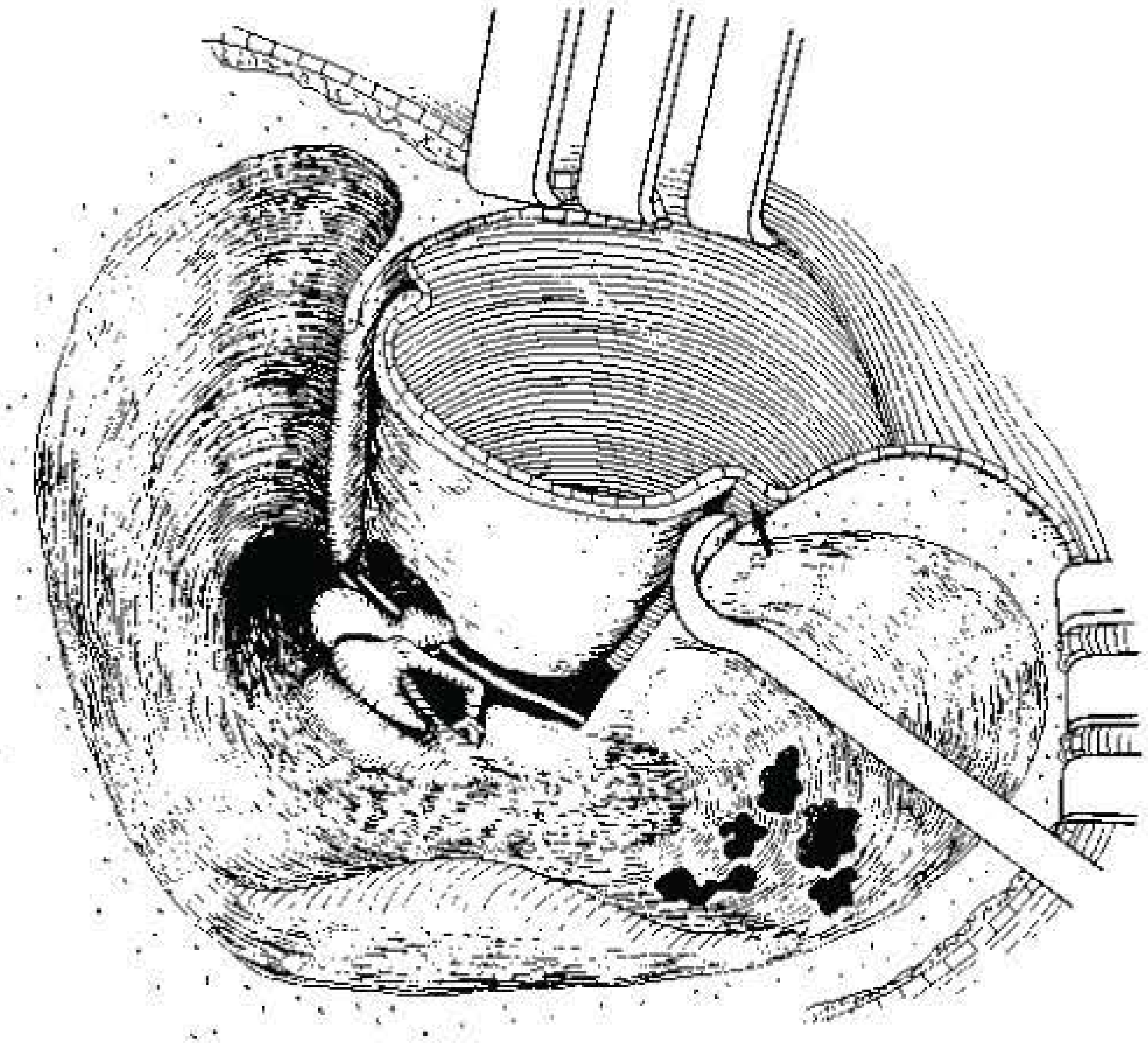


Fig. **496** With a curved rugine, the periosteum and the ear canal skin are carefully elevated along the osteotomies, maintaining the canal skin intact (arrow). Superiorly, the ear canal wall is rotated clockwise, opening the anterior attic

normal position (Fig. **498**), and the transcanal part of the procedure ensues with ossiculoplasty, closure of the drum perforation with underlay vein or fascia graft, and replacement of the ear canal skin. Care is taken to cover the resulting defects in the bone (Fig. **499**). Lastly, the ear canal is filled with Gelfoam.

Initially, Schnee (1963, 1964) used an endaural approach with a plastic tube inserted into the mastoid cavity and brought out through the endaural incision. Later, he changed the method, and preferred a retroauricular approach (Schnee 1969) that avoided the transmeatal atticotomy whilst maintaining the attachment of the tympanic membrane and ear canal skin to the mobilized bony ear canal.

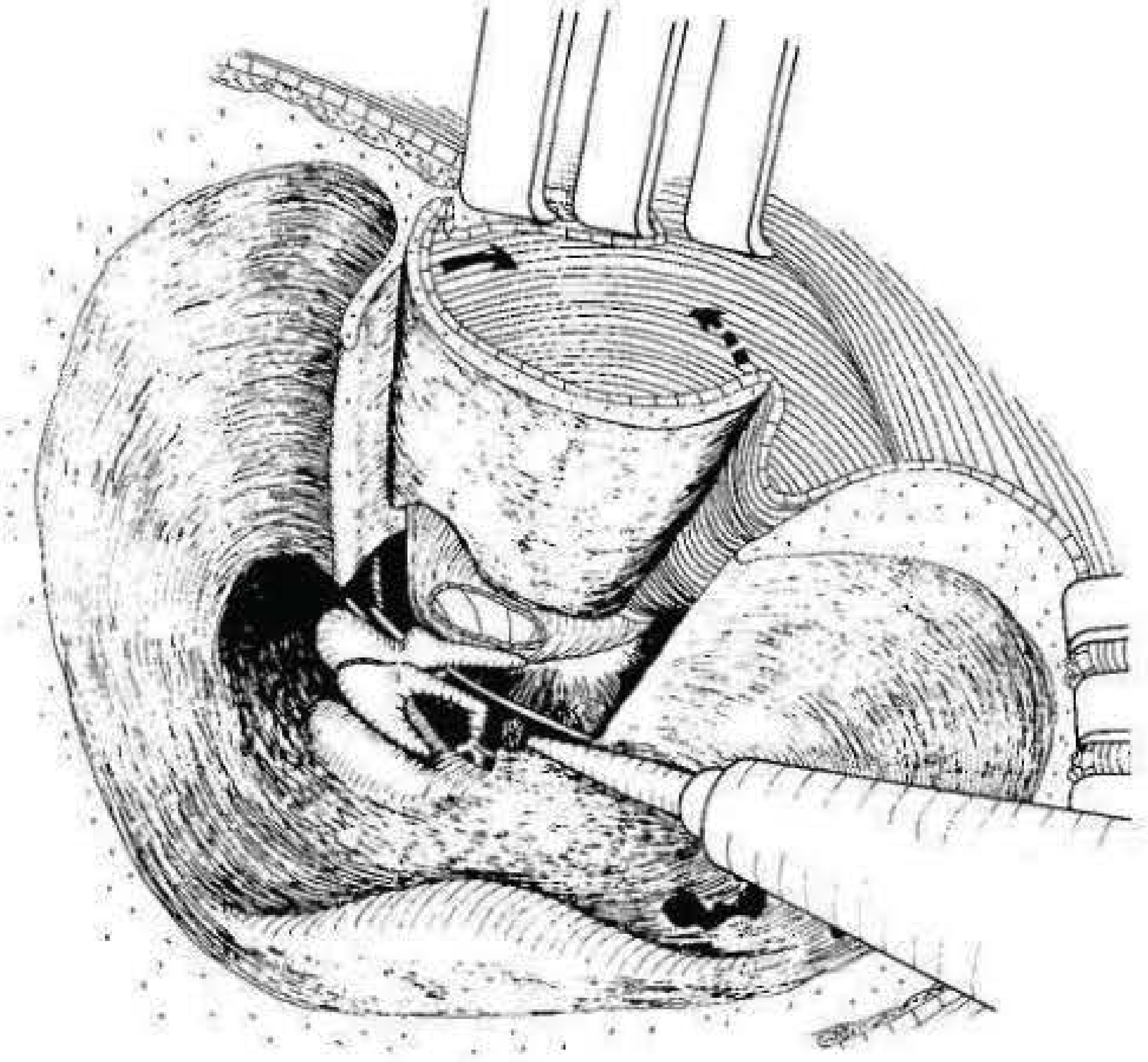


Fig. **497** The entire ear canal wall is displaced anteriorly, exposing the malleus handle and the drum. The ear canal can be rotated clockwise (solid arrow) if a larger space is desired superiorly, or anticlockwise (dashed arrow) if the hypotympanum has to be exposed. The bone from the facial recess, medial to the preserved chorda tympani, is removed to enlarge the exposure of the tympanic sinus

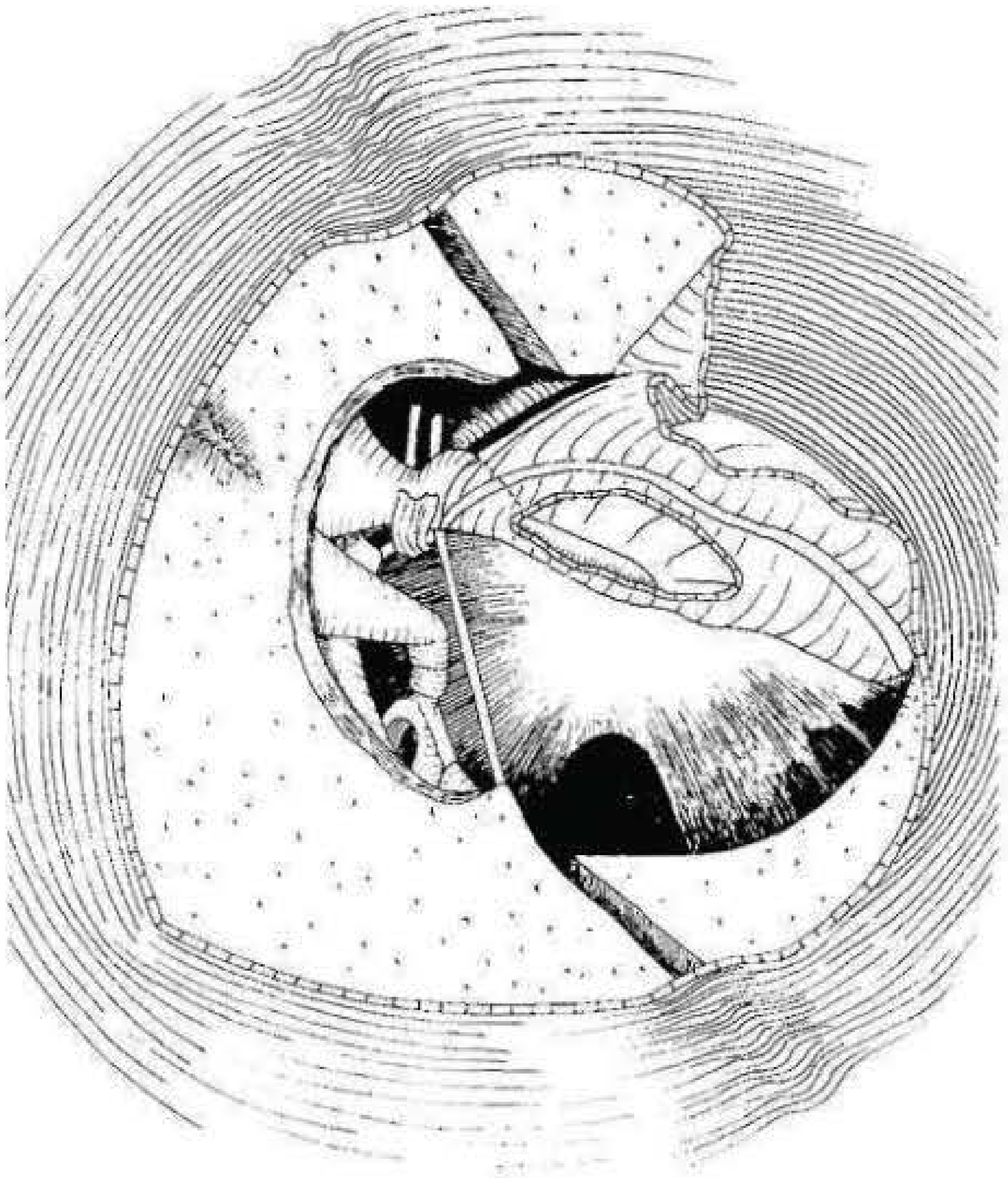


Fig. **498** The transmeatal view of the replaced ear canal wall, illustrating the bone defects caused by drilling and the areas with elevated skin

Posterior Wall Displacement

After transmeatal clearing of cholesteatoma from the tympanic cavity and deepithelialization of the drum remnant, as well as removal of the margins of the perforation, without elevating the canal skin a simple atticomastoidectomy is performed through a retroauricular approach (Lapidot and Brandow 1966). The posterior bony ear canal wall is thinned, and the incus body and the short process of the incus, the posterior buttress, the lateral semicircular canal and the facial nerve are located (Fig. **500**). Holes are drilled in the ear canal wall for the superior and inferior osteotomies, using a small cutting burr. The superior vertical osteotomy is made below the level of the superior buttress, starting at the lateral free margin of the bony ear canal. A similar, parallel, inferior osteotomy is made at the level of the floor of the external bony ear canal. These two vertical osteotomies are then connected by a horizontal osteotomy, approximately 1-2 mm lateral to the facial ridge. The isolated bony ear canal wall is carefully elevated and pushed anteriorly, together with its attached ear canal skin and the annulus of

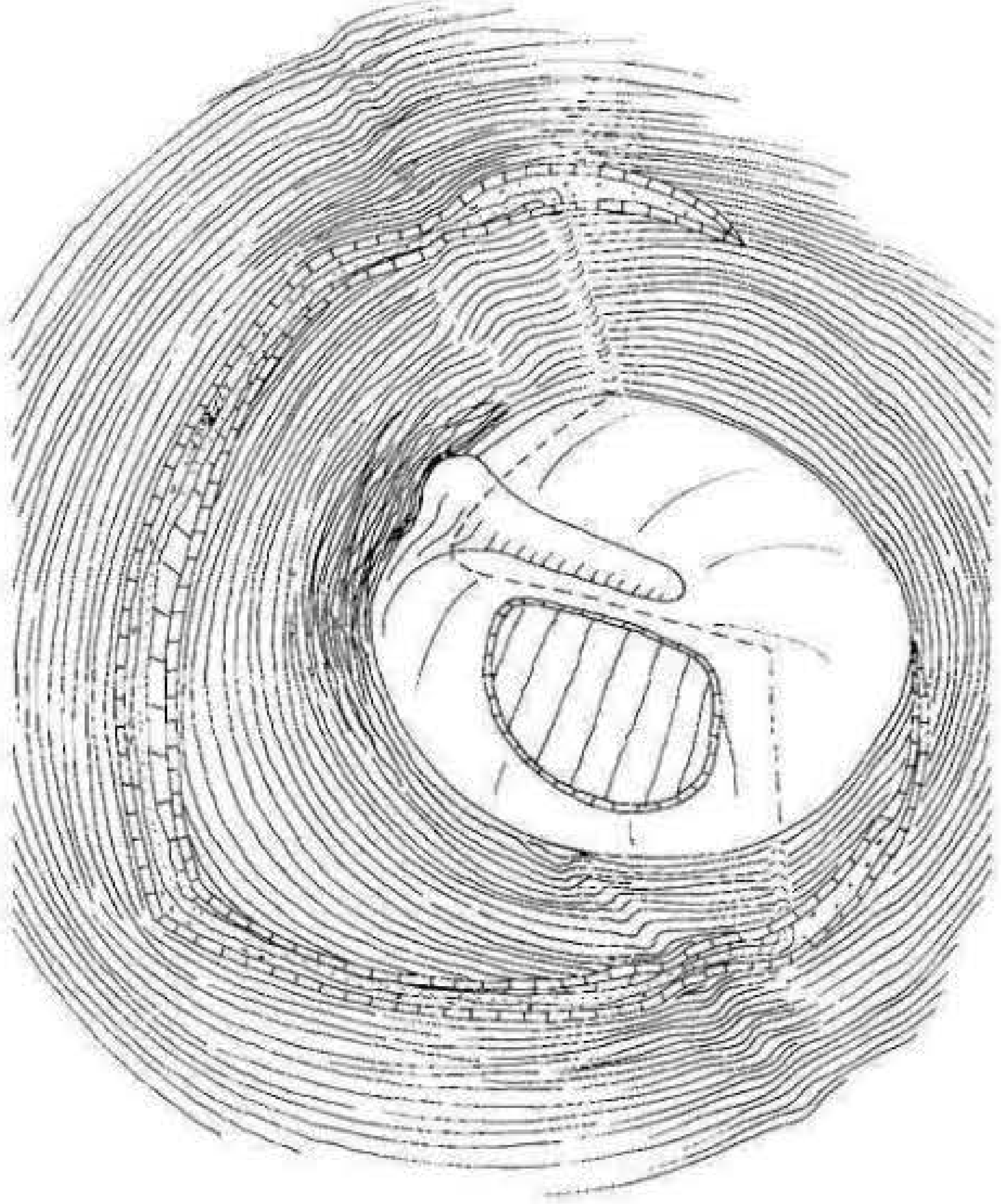


Fig. **499** The fascia or vein covers the perforation, and the exposed bony ear canal wall, with the osteotomy grooves and the ear canal skin flaps are replaced

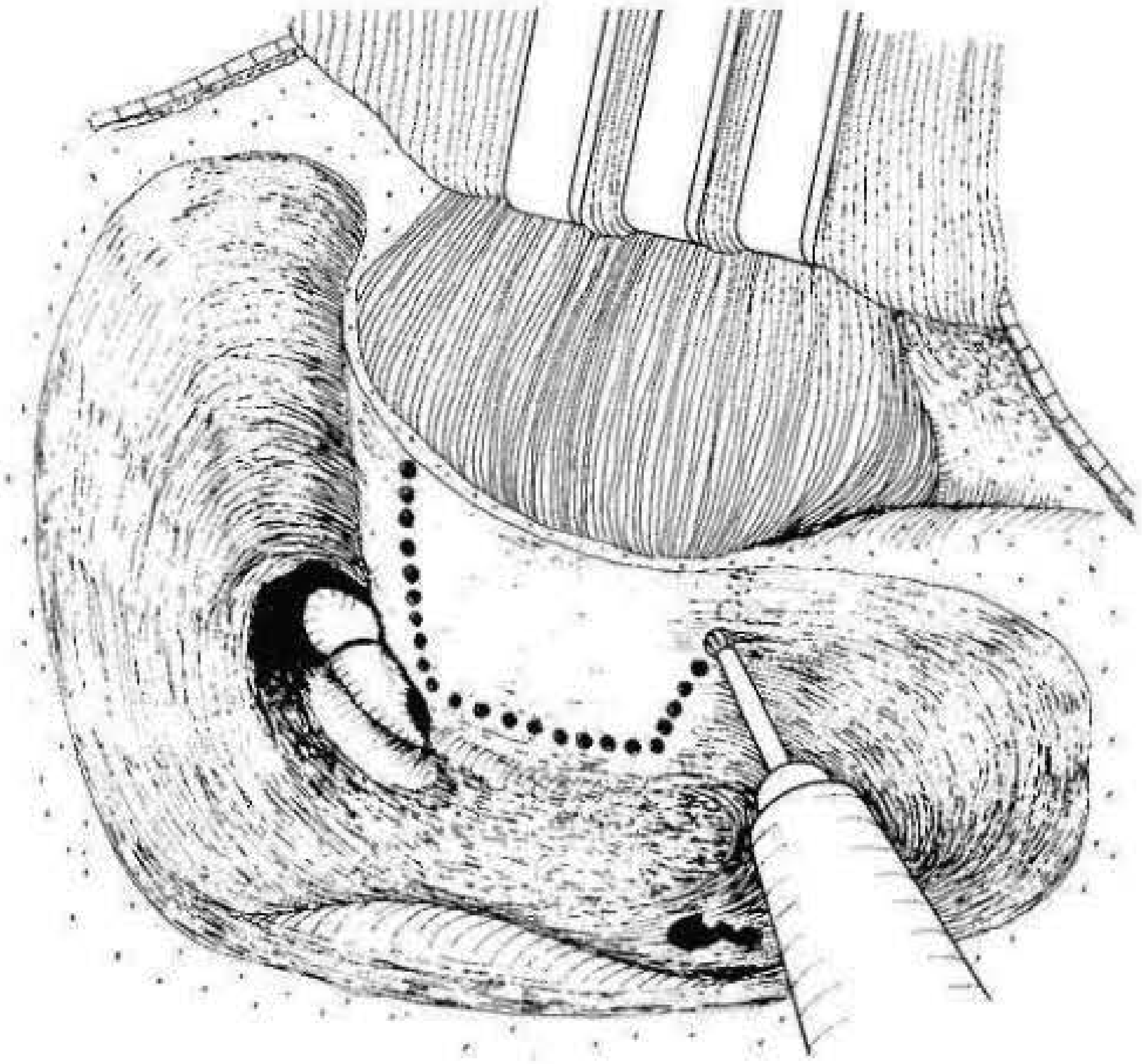


Fig. **500** **The posterior wall displacement (Lapidot and Brandow).** After an intact canal wall mastoidectomy in a retroauricular approach without opening the ear canal skin, the thinning of the bony ear canal wall, especially its posterior part, is performed. Small holes are made in the bony ear canal wall, indicating the superior, inferior, and horizontal osteotomies. The superior osteotomy is performed at the level of the posterior buttress, the inferior at the bottom of the ear canal, and the horizontal about 1-2 mm lateral to the facial nerve, which is partly skeletonized

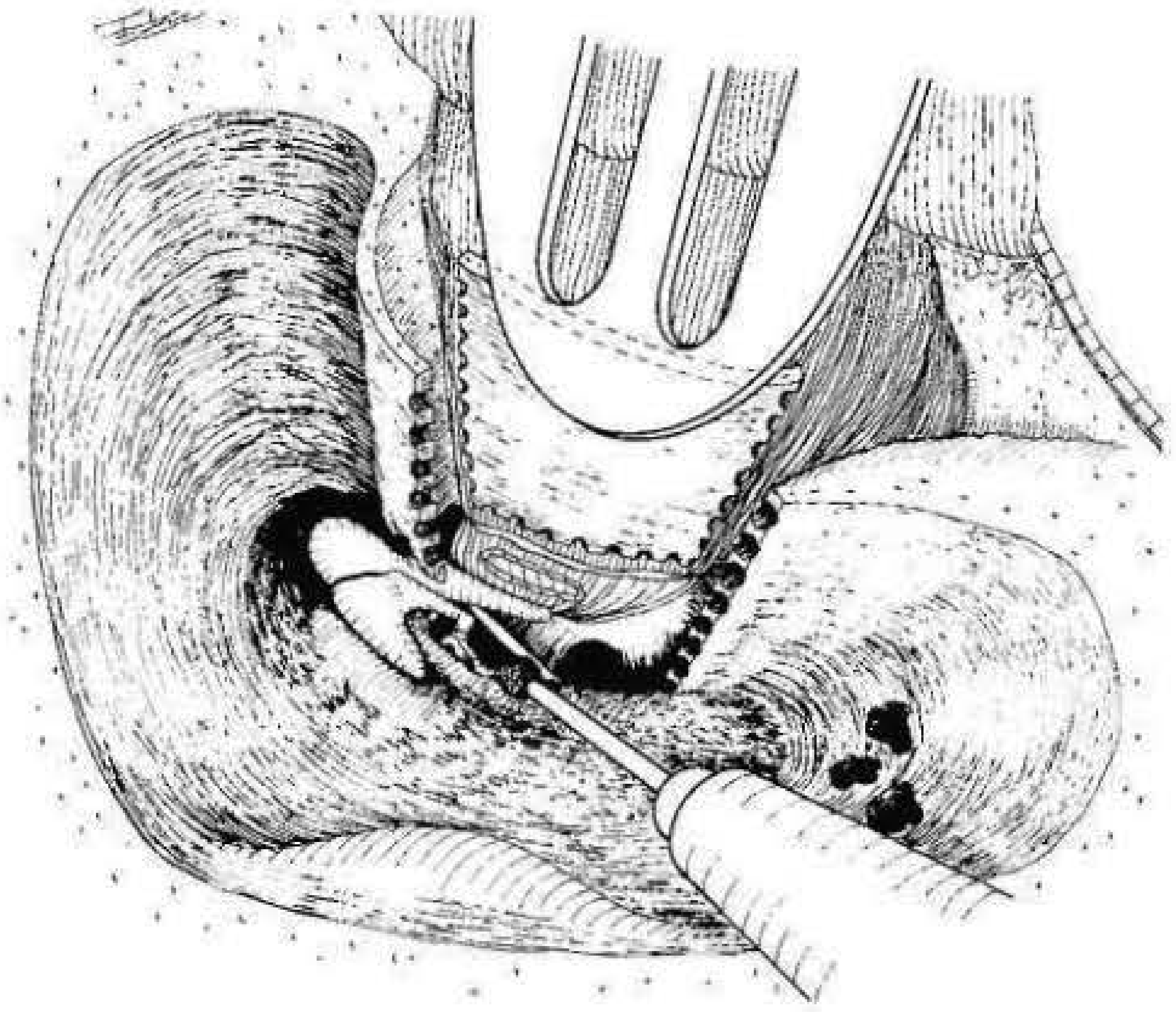


Fig. **501** The osteotomies have been completed, and the posterior ear canal wall has been displaced anteriorly, together with the intact ear canal skin attached to the mobilized bony ear canal wall. Also, the fibrous annulus is displaced anteriorly, exposing the ossicular chain and partly the posterior part of the tympanic cavity. By drilling the bone within the facial recess using a diamond burr, the posterior tympanum can be further exposed

the tympanic membrane, leaving the posterior part of the bridge intact (Fig. **501**). The ear canal skin and the mobilized bony ear canal wall must be held in place by a selfretaining retractor with a long blade. After the cholesteatoma removal and underlay fascia grafting of the perforation are complete, the bony ear canal wall is replaced and the ear canal is packed.

Mobilization of the posterior ear canal wall provides good exposure of the promontory, hypotympanum, and the anterior tympanum, but the posterior tympanum with the tympanic sinuses is not satisfactorily exposed, because the horizontal osteotomy is 1-2 mm lateral to the facial ridge. Further bone removal from the facial recess (Fig. **501**) and around the chorda is necessary to obtain a sufficient viev of the tympanic sinuses. The Lapidot method is, in the present author's opinion, only suitable for sinus cholesteatoma, because the superior osteotomy is made below the posterior buttress, and the superior part of the ear canal is not mobilized at all. In cases of attic cholesteatoma, this method cannot be used, since the anterior attic is not opened. The anterior attic can in fact be approached "transmeatally" after the bony ear canal has been displaced anteriorly (Fig. **501**), but then the philosophy of the completely intact ear canal is lost, and a scutumplasty is difficult to perform.

Richards' Mobile Bridge Technique

Richards (1972) recognized the difficulties of the Schnee technique with the elevation of a large tympanomeatal flap (Figs. **490, 491**), which leaves very little of the canal skin attached to the mobilized bony ear canal. For this reason, Richards does not start transmeatally, and keeps all the canal skin attached to the mobilized bony ear canal and bridge. He also performs a posterior atticotympanotomy through the facial recess, as well as a transmastoid anterior atticotympanotomy.

Richards performs the mastoidectomy with a retroauricular approach, thinning the bony ear canal wall anteriorly to expose the extreme anterior portion of the attic. The incus and malleus are located, and the posterior atticotympanotomy is performed in the usual manner, removing the posterior buttress (Fig. **502**). After a superior and an inferior osteotomy using a small cutting burr, the bony ear canal with the bridge is mobilized, but the attachment to the ear canal skin anteriorly is retained (Fig. **503**). The mobilized bridge is then displaced anteriorly, exposing the middle ear space (Fig. **504**).

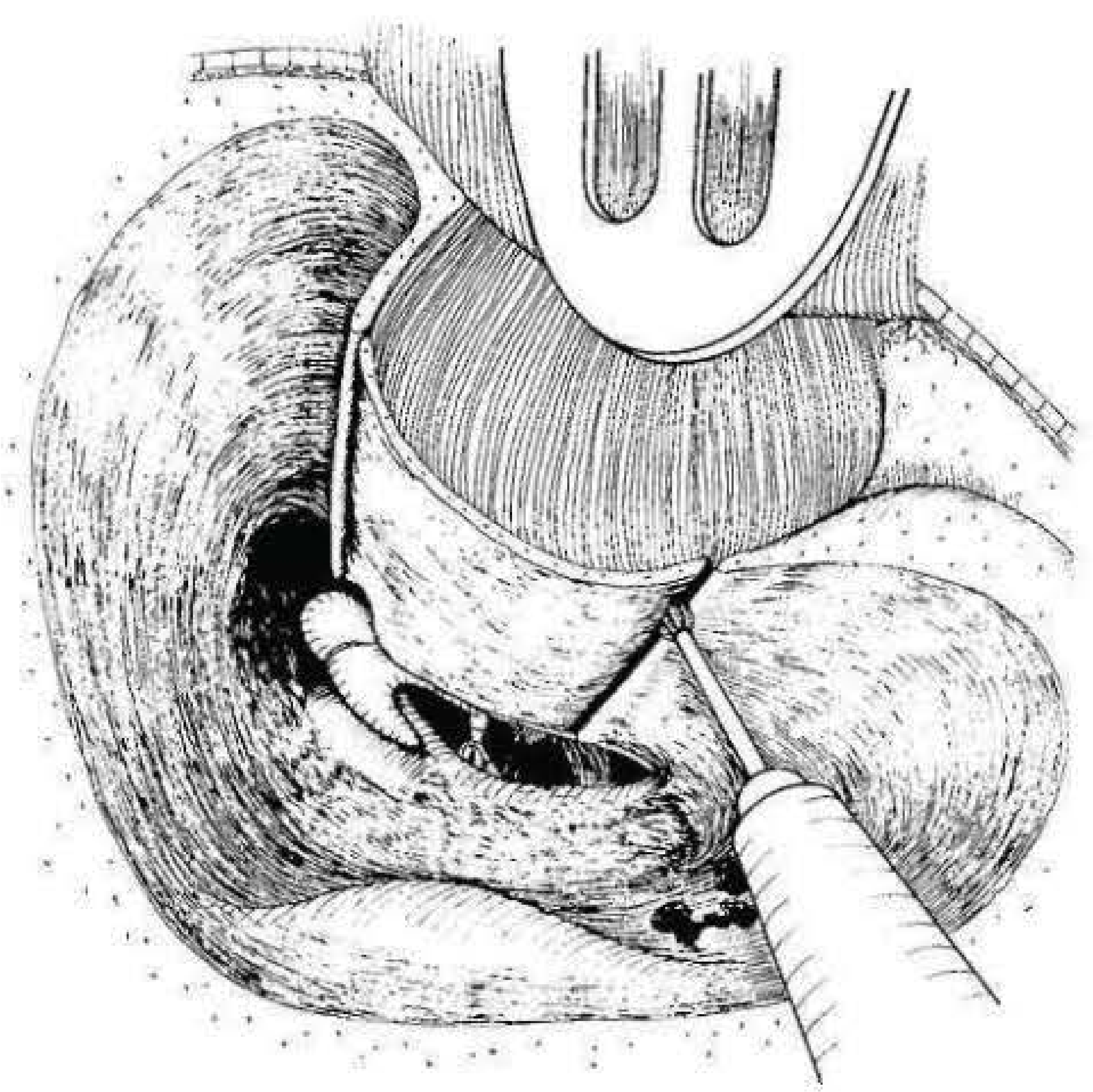


Fig. **502** **Richards' mobile bridge technique.** In the retroauricular approach preserving the entire canal skin attached to the bony ear canal wall, an intact canal wall mastoidectomy is performed by thinning the posterior canal wall far anteriorly, exposing the anterior attic, and performing a posterior atticotympanotomy with removal of the posterior buttress. The long process of the incus and the stapes are exposed. The superior osteotomy, starting anterior to the head of the malleus, and the inferior osteotomy, starting at the 8-o'clock position lateral to the chorda tympani, are performed with a small cutting burr

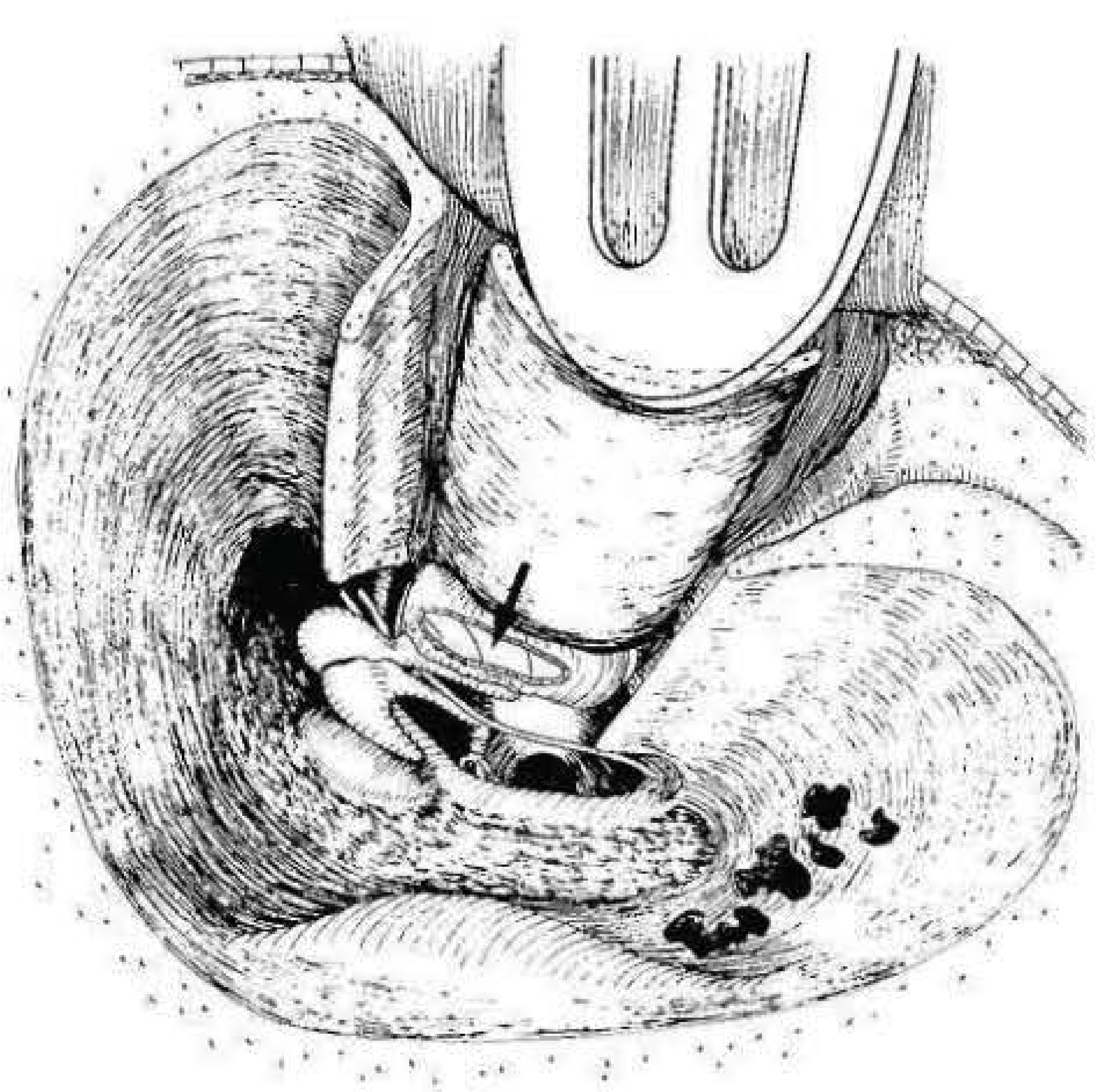


Fig. **503** The bony ear canal wall is mobilized and pushed anteriorly after the canal skin has been detached from the bony ear canal, close to the osteotomies. Together, with the ear canal wall, the fibrous annulus and the drum remnant are also mobilized, exposing the posterior perforation (arrow), the ossicles, the posterior tympanum, and the attic

After the tympanic and the mastoid cavities have been cleared of cholesteatoma and after ossicular reconstruction, the perforation is closed with an underlay fascia graft, and the mobilized bridge is replaced and kept in position by a gauze pack placed in the external ear canal (Fig. **505**). The reconstructed ossicular chain is inspected through the posterior atticotympanotomy. The posterior end of the fascial graft is brought into the mastoid cavity through the posterior atticotympanotomy, and is then placed on the posterior surface of the bony bridge. In this position, it is supported by Gelfoam balls placed on the mastoid surface of the bony ear canal wall (Fig. **506**).

Richards reported the following complications among 76 consecutive cases: two cases with temporary facial palsy, two with bone breakdown, and one with ear canal stenosis. In two ears with extensive spontaneous erosion of the ear canal wall, the mobile bridge technique was not possible. Late results in 40 cases with at least 18 months of observation time showed cholesteatoma in one case, otorrhea in three cases, and retraction pockets in five cases, but none were severe.

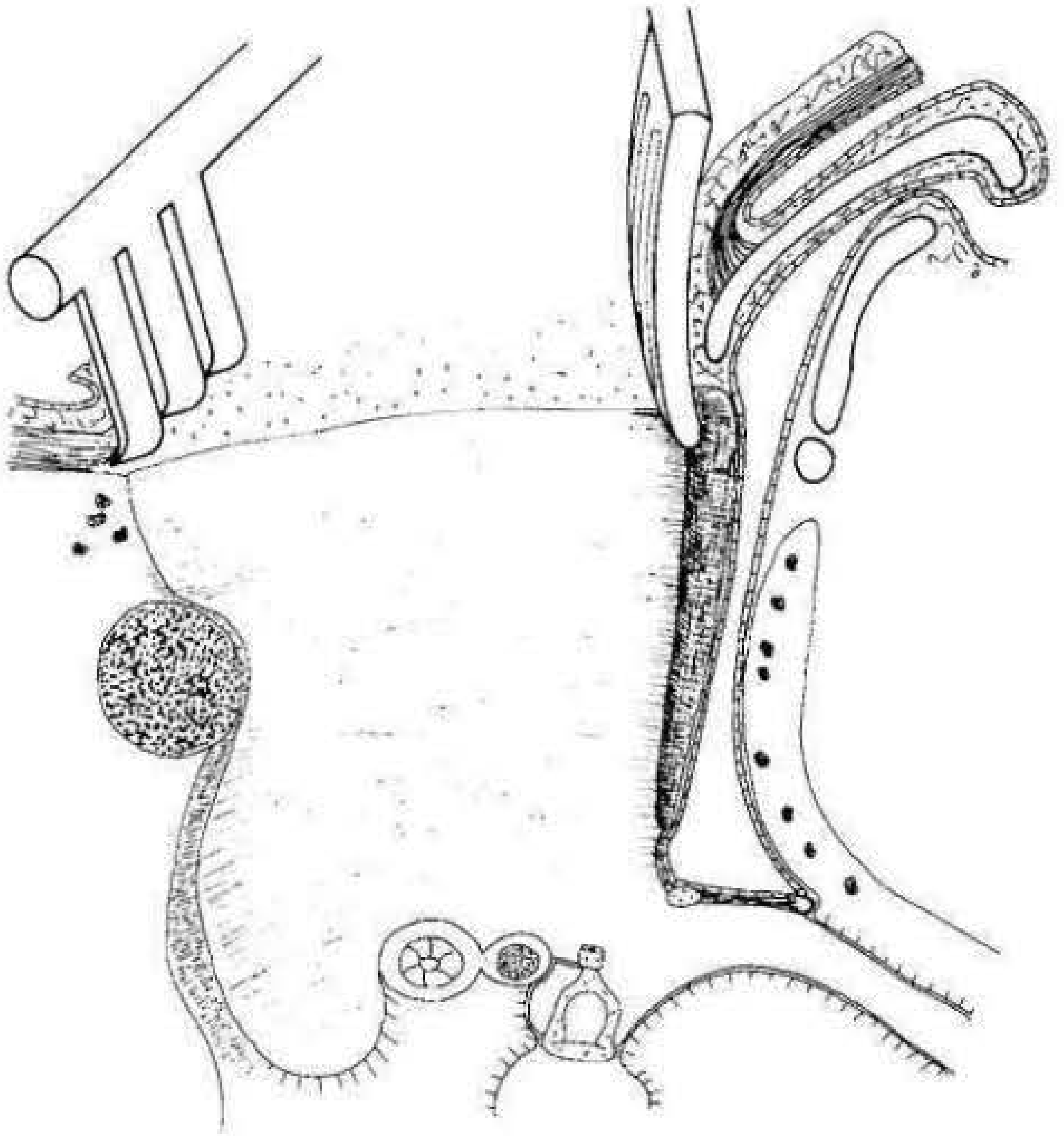


Fig. **504** Side view of Richards' mobile bridge technique. The mobilized bony ear canal wall is anterior displaced and held in place with the protective blade of a selfretaining retractor. The medial part of the bony ear canal is connected to the ear canal skin and the drum remnant. Good exposure of the attic and the tympanic cavity is illustrated

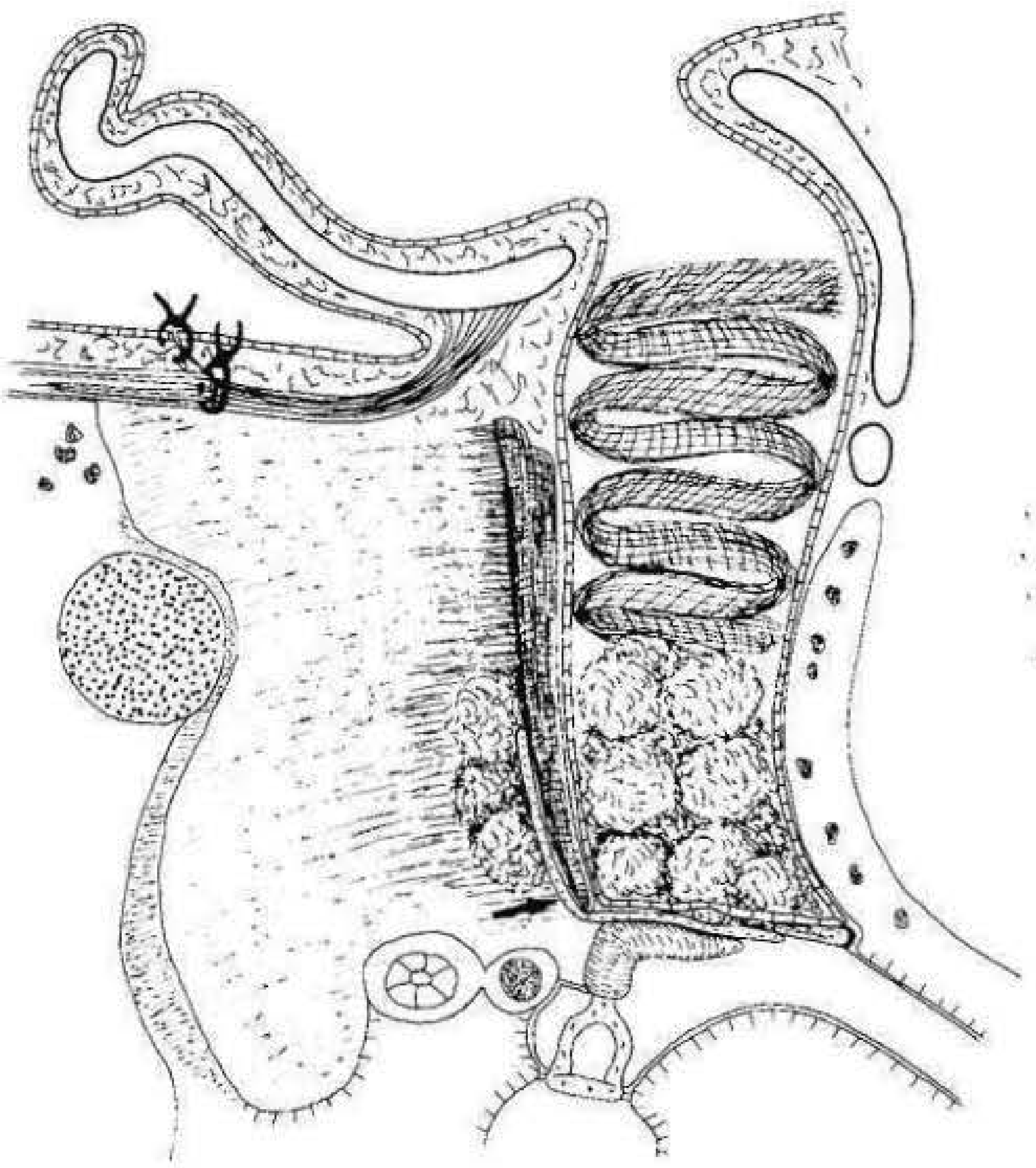


Fig. **505** Side view of the repositioned bony ear canal wall, placed back in its original position. The ossiculoplasty is performed with a shaped autogenous incus, placed under the malleus handle and the fascia. The temporalis fascia, as an underlay graft, is placed behind the bony ear canal wall (arrow) and held in place with some Gelfoam balls

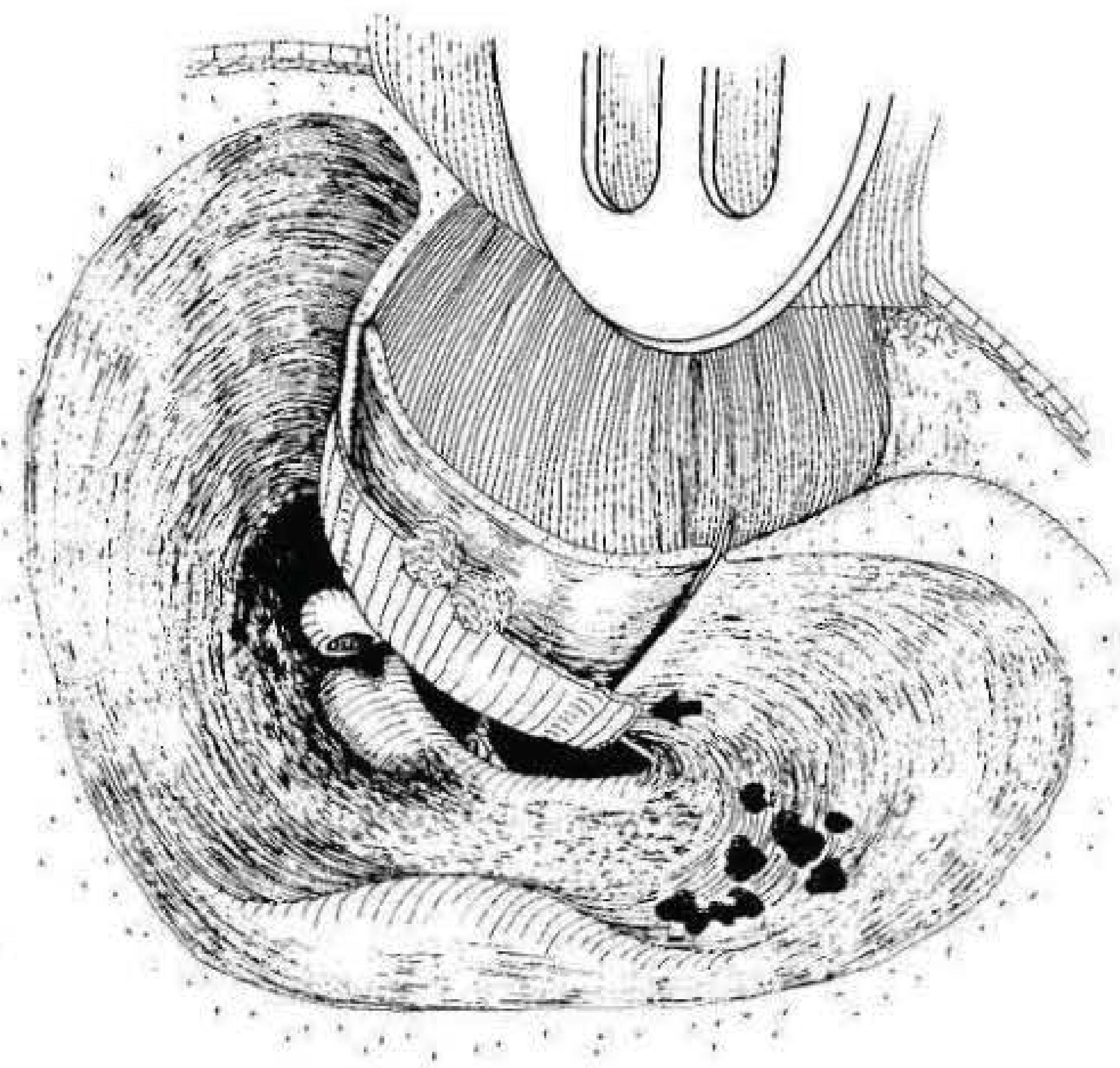


Fig. **506** Replaced bony ear canal wall, supported by the fascia folded around the medial edge of the ear canal and fixed on its mastoid aspect with Gelfoam balls (arrow)

Temporary Removal of the Bony Ear Canal Wall

The methods using temporary removal of the ear canal have partly replaced displacement techniques, because they are easier to perform and can provide better exposure of the anterior part of the tympanic cavity and Eustachian tube orifice. In addition, surgeons are more familiar with the approach, including elevation of the ear canal skin. Lastly, there is the possibility of better fixation of the replaced bone, which contributes to the popularity of these methods.

Temporary Meatotomy

Gerlach (1969 a) was the first to remove the bony ear canal wall in cases with extensive cholesteatoma. He called his method "temporary meatotomy." The ear canal skin, with the fibrous annulus and the drum remnant, were elevated from the bony canal wall. After osteotomies and removal of the bony ear canal wall, an excellent view of the cholesteatoma is achieved, and it can be removed in toto. After replacement, the bony ear canal wall is supported by a superiorly pedicled fascia-muscle flap from the temporalis muscle (Gerlach 1969 b) (Fig. **507**). Gerlach (1970) fixed the ear canal wall with Histoacryl glue, and homogenous bone paté was placed in the osteotomy grooves. However, in several cases he observed retraction of the replaced canal wall, with formation of defects in the meatal side of the ear canal — a stair-like formation — similar to the complication seen after longitudinal temporal bone fracture with dislocation running through the ear canal.

Osteoplastic Epitympanotomy (S. Wullstein)

With the introduction of osteoplastic epitympanotomy, Sabina Wullstein (1972, 1973, 1974) caused a resurgence of interest in temporary removal of the bony bridge. The principle of this technique has been described here earlier (Vol. I, Chapter 5) together with a description of the superior approach, which is a characteristic feature of the superior epitympanotomy (Vol. 1, Figs. **159–161).** Through maximal widening of the superior bony ear canal, a bony plateau is elaborated, extending from the bony annulus inferiorly to the middle fossa dural plate superiorly. With further drilling of the lateral wall of the attic and thinning of the roof of the bony meatus close to the middle fossa dural plate (Vol. 1, Fig. **162**), the lateral attic wall is maximally thinned. The drilling is extended further medially and anteriorly at the zygomatic root, making the bony plate that is about to be removed as large as possible and exposing the entire anterior attic. Using a small diamond burr, a groove is created (Vol. 1, Fig. **163**), the bony plate is elevated, and the lateral attic as well as the superior and posterior tympanum are thus exposed. Precise surgery in the anterior attic, and especially the creation of a ventilation route through the epitympanic sinus to the Eustachian tube, is possible and easy to perform (Vol. 1, Fig. **166**).

Removal of an *attic cholesteatoma* located in the lateral attic, preserving the ossicular chain intact, can be performed in a similar way to that described in Chapter 7. above with elevation of the cholesteatoma membrane from the lateral aspects of the incus body and head of the malleus, and cleaning of the anterior attic. In cases with a defective long process of the incus, the incus is removed, and the cholesteatoma can be removed from around the malleus head, preserving it intact — of course, as long as there is no invasion of cholesteatoma into the ossicle.

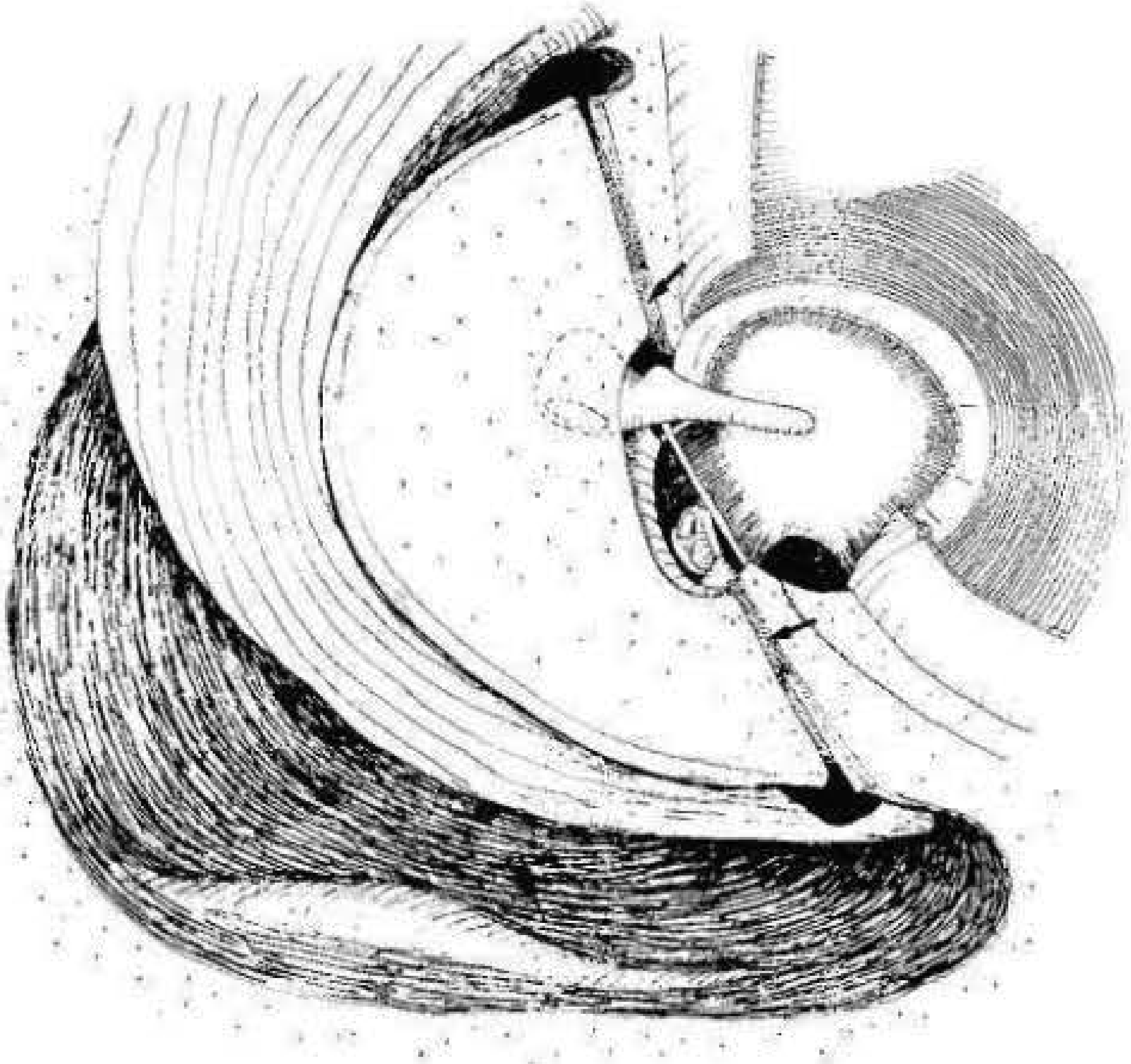


Fig. **507** **Gerlach's temporary meatotomy.** After an intact canal wall mastoidectomy and superior and inferior osteotomies using small burrs, the bony ear canal has been removed and the cholesteatoma has been removed, leaving a total perforation, an intact malleus, and an intact stapes. The bony ear canal wall is replaced in its original position and glued from behind with Histoacryl glue, or nowadays replaced with Ionomer cement (dark spots). The bony ear canal is supported by a superiorly pedicled fascia-muscle flap placed behind the ear canal wall. The defects after the osteotomies are filled with homgenous bone paté (arrows)

In cases with cholesteatoma extending onto the medial surface of the incus and malleus head, the incus body has to be removed, and sometimes even the malleus head has to be resected, but in the superior approach the chance of cleaning the ossicles in the attic is optimized.

In *sinus cholesteatoma,* defined as a posterosuperior retraction involving the tympanic sinuses and the stapes, the cholesteatoma removal is relatively easy and safe, because the removal of the posterior bony annulus (otosclerosis drilling) can be extended in order to totally visualize the lateral and the medial sinuses. The view of the stapes and the footplate region is similarly good in the superior approach. In cases with an eroded incus, the cholesteatoma may extend medial to the incus body, but it can be removed safely after removal of the incus body and cleaning of the medial attic.

In *tensa retraction cholesteatoma* involving the entire tympanic cavity with retraction and adhesion of the entire pars tensa, or a total perforation, there is a good view of the tympanic cavity with the superior approach after the ear canal has been opened (Fig. **508**). The cholesteatoma membrane is easily elevated, starting superiorly and continuing down to the annulus.

Reconstruction of the Osteoplastic Epitympanotomies

Reconstruction is relatively easy, because the groove on the bony lid is not made through the entire lateral attic wall, and in fact the bony lid is fractured out, so that replacement is easy. The bony lid is placed on the defect, and the fascia covering the attic perforation is placed on the malleus neck and under the superior edge of the drum remnant. Before being covered with fascia, the grooves along the bony lid can be covered by bone paté and fibrin glue, if desired (Fig. **509**). Finally, the fascia and the epithelial flaps are replaced (Fig. **510**). There are no problems with epithelialization of the sclerotic bone

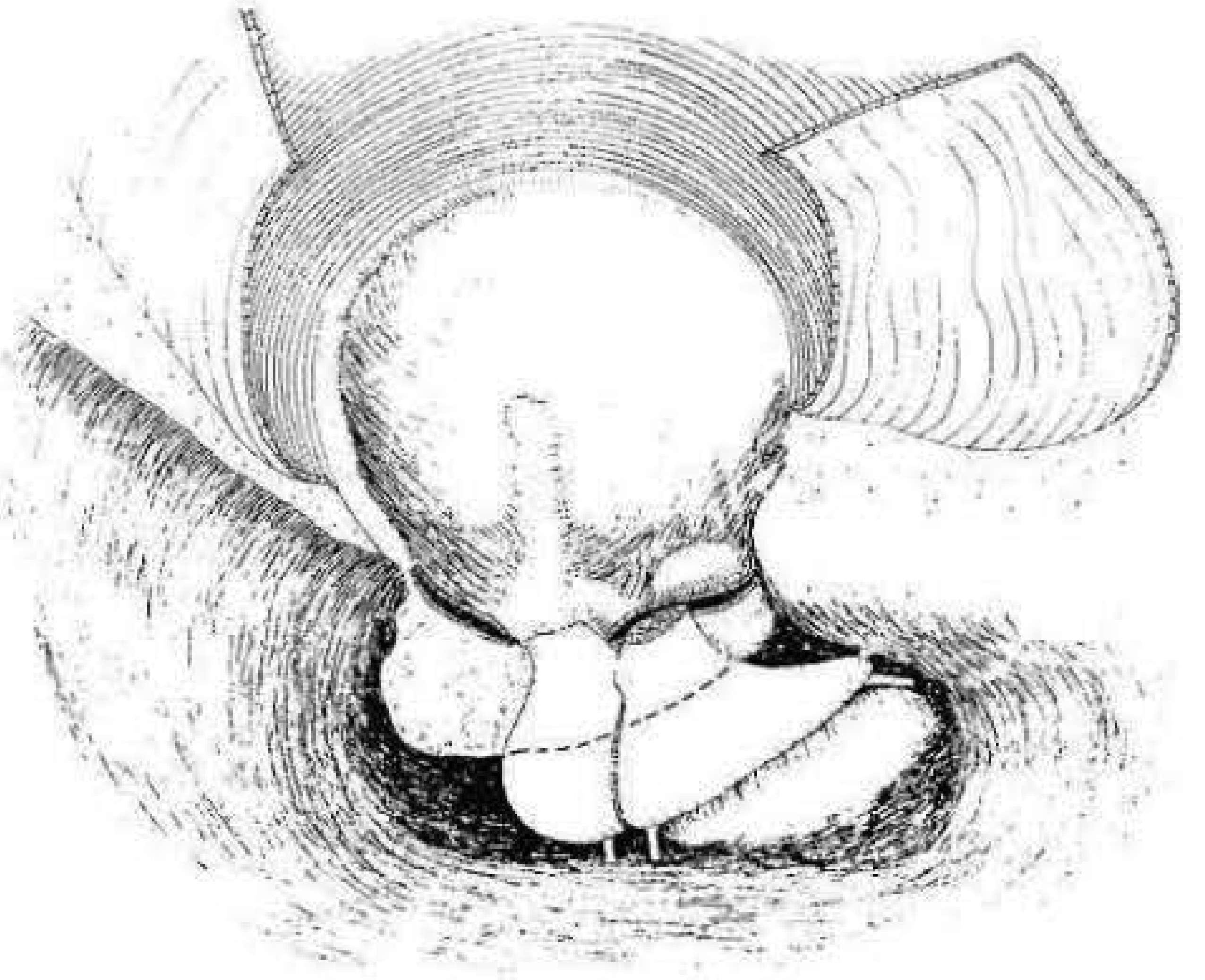


Fig. **508** **Osteoplastic epitympanotomy (S. Wullstein)** performed in a superior approach, with the surgeon sitting at the top of the patient's head and looking into the tympanic cavity in a superoinferior direction. An osteoplastic tympanotomy is performed, with enlargement of the ear canal up to the middle fossa dural plate, and a bony plate from lateral attic is removed, exposing a tensa retraction cholesteatoma. After cutting the ear canal skin at the 12-o'clock position and creating anterior and posterior ear canal skin flaps, a good view of the tympanic cavity is achieved, illustrating the retraction of the entire atrophic pars tensa under the annulus, into the orifice of the Eustachian tube, and around the malleus handle, resorbing the stapes and the long process of the incus. The cholesteatoma extends anteriorly under the anterior malleolar fold, under the head of the malleus. and into the anterior and medial attic. Posteriorly, the cholesteatoma extends medial to the incus body into the tympanic isthmus

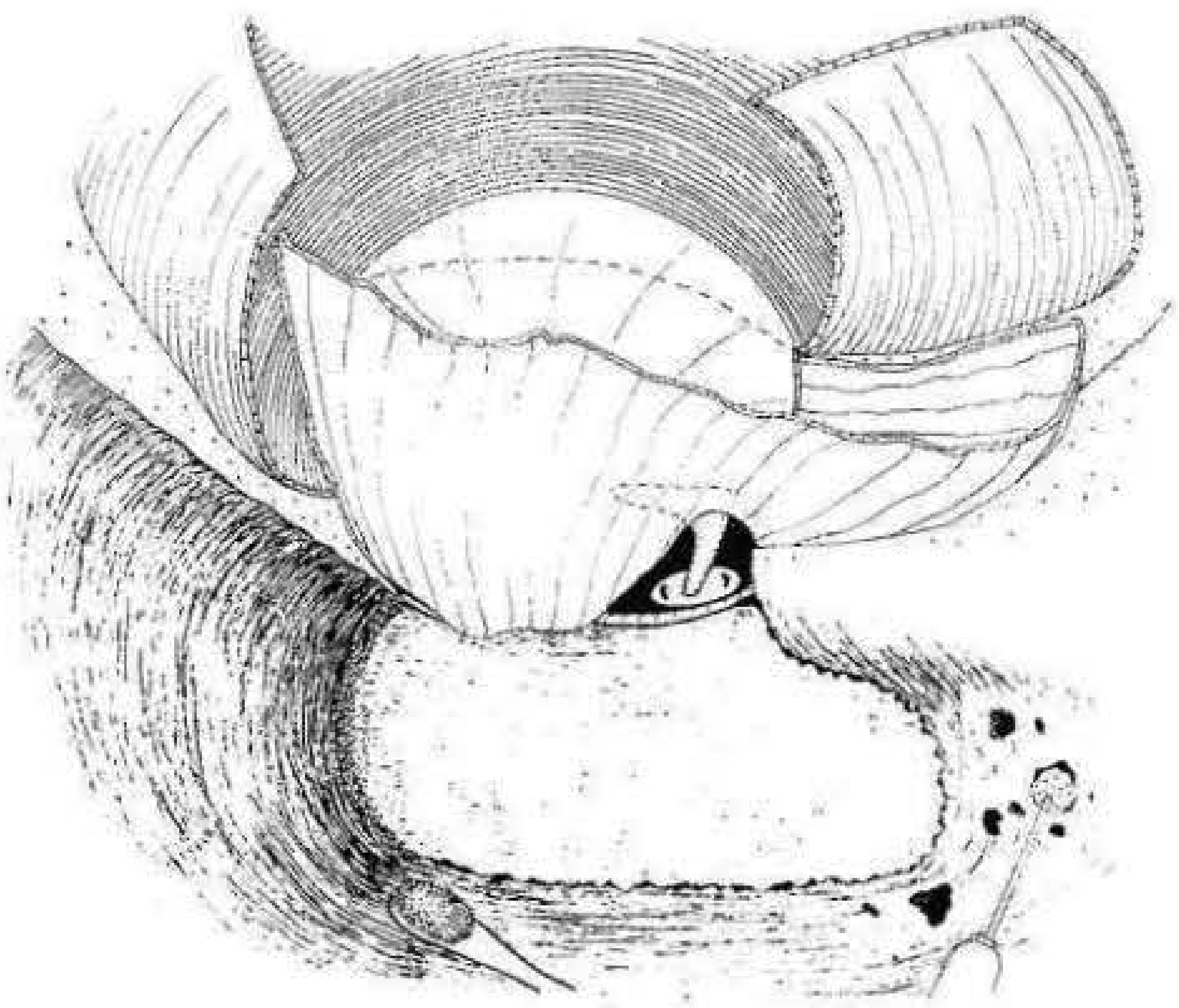


Fig. **509** **Reconstructon of the osteoplastic epitympanotomy.** The bony plate is inserted. Bone paté or fibrin glue can be placed in the groove, or used to close a large air cell. Fascia, already placed and fixed under the ear drum remnant and on the malleus neck, is temporary placed on the posterior aspect of the meatal skin to cover the repositioned bony plate

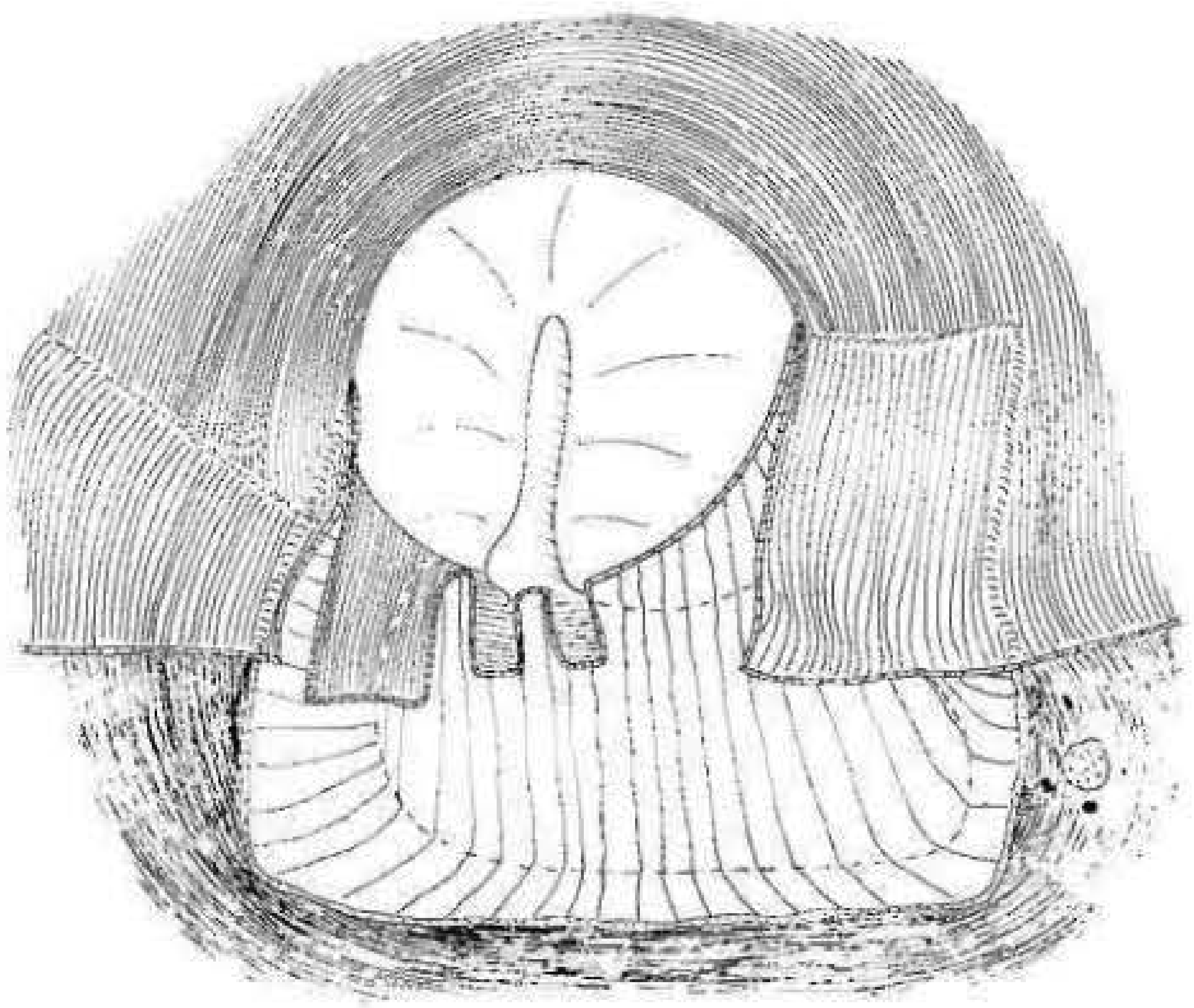


Fig. **510** The fascia is covering the bony plate and the groove, as well as some air cells, and the meatal skin flaps are replaced

if no air cells have been opened. If the air cells are open, they can be filled with bone dust, or covered with fascia separately. At the end of the operation, of course, the ear canal has to be widened with an incision at the 12-o'clock position. The osteoplastic epitympanotomy is best in cases with a sclerotic mastoid process, because a solid bony plate can be achieved. In cases with extensive penumatization and extension of the cholesteatoma into the attic, a large bony plate is needed, and it is not always easy to achieve this. If the pathology requires an extended mastoidectomy, there will be a gap between the bony plate and the defect to be covered. Such a defect can be filled with bone dust or pieces of bone fixed to the bony plate with fibrin glue.

Osteoplastic Epitympanotomy and Mastoidectomy

If the retrotympanic spaces and the entire mastoid process have to be opened, it is still possible to achieve osteoplastic closure of the middle ear space with connection of the posterior segment to the function of the anterior segment. Two different methods can be used (Wullstein and Wullstein 1990).

1. A canal wall–up mastoidectomy with a posterior tympanotomy in the inferior part of the mastoid tegmen, so that the ear canal wall is intact as far as 9-o'clock (Fig. **511**). **a)** The attic can be reconstructed as in an osteoplastic epitympanotomy, and the remainder of the cavity can be ventilated. **b)** Instead of repneumatization, the inferior part of the cavity can be obliterated by filling with bone dust, bone chips, tragal cartilage, autogenous muscle, or hydroxyapatite. The osteoplastic epitympanotomy can be completed and covered with the bony plate in order to ventilate the attic (Fig. **511**).
2. The other option is to perform a separate mastoidectomy in the inferior part of the mastoid process (Fig. **512**). The inferior part of the ear canal remains intact, and a posterior atticotympanotomy is performed to ventilate the cavity from the posterior tympanum. **a)** The separate mastoidectomy can be ventilated through the attic, after covering the osteoplastic epitympanotomy, or through the posterior atticotympanotomy. **b)** The separate mastoid cavity can be obliterated in various ways, as mentioned above. In the osteoplastic method, the atticotomy will be covered with reposition of the lid (Wullstein and Wullstein 1990).

Portmann's Technique

Portmann (1979), using his own posterosuperior incision in a retroauricular approach with an incision through the postauricular subcutis and periosteum close to the entrance of the bony meatus (Vol. 1, Figs. **123–131**), elevates the posterior ear canal skin as a laterally based flap, using a strip of gauze placed through the external auditory meatus (Fig. **513**).

After a classic intact canal wall mastoidectomy and a large posterior atticotympanotomy with removal of the incus (Fig. **513**), two osteotomies are performed, either with a small cutting burr or a Gigli microsaw. The inferior osteotomy is placed at the level of the round window niche, cutting the chorda tympani before continuing laterally. The superior osteotomy is placed just superior to the tympanic notch (incisure of Rivinus), adjacent to the malleus.

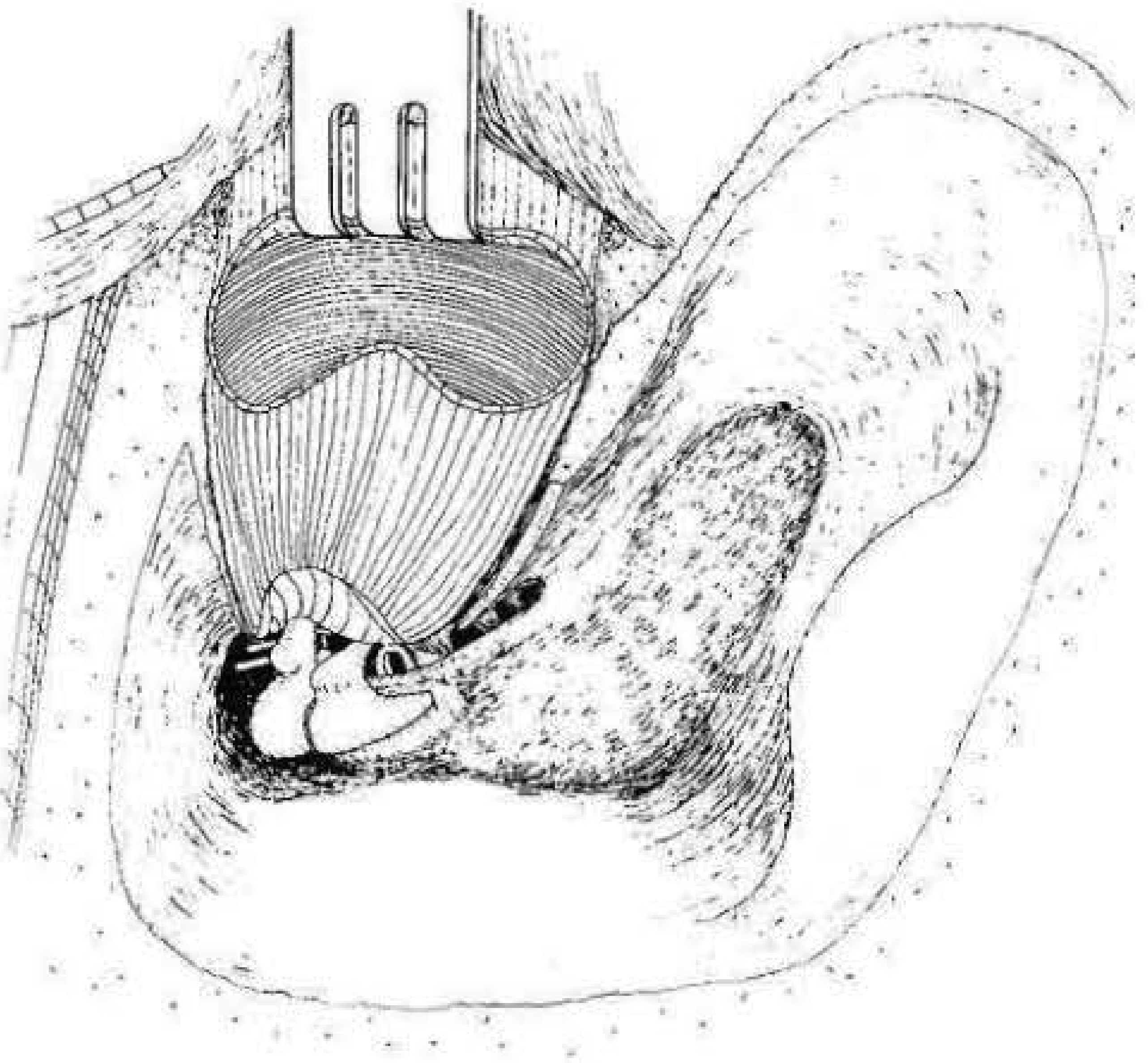


Fig. **511** **Osteoplastic epitympanotomy and extended mastoidectomy (Wullstein and Wullstein)** seen through the superior approach as in Figures **508** to **510**, with the surgeon sitting at the top of the patient's head. The bony ear canal wall is intact from the 9-o'clock position to the bottom, and a posterior atticotympanotomy is performed (arrow). The mastoid cavity can be either repneumatized or obliterated separately

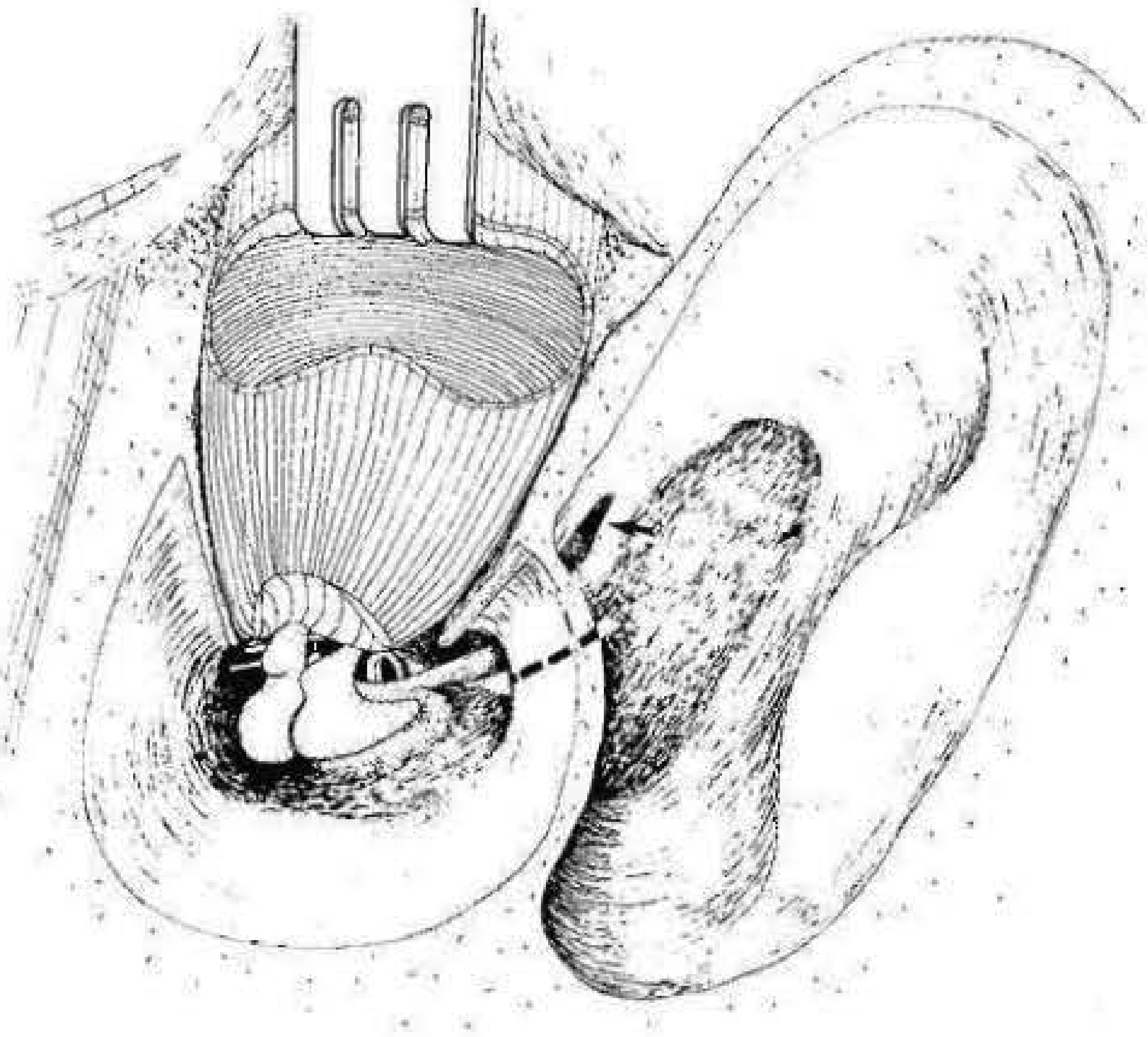


Fig. **512** **Osteoplastic epitympanotomy and a separate mastoidectomy in the inferior half of the mastoid process (Wullstein and Wullstein),** seen through the superior approach. An osteoplastic atticotympanotomy is performed, and a bony wall between the attic and the mastoid cavity remains. The mastoid cavity can be ventilated through a posterior atticotympanotomy (arrow) and through the attic (dashed arrow), or it can be obliterated

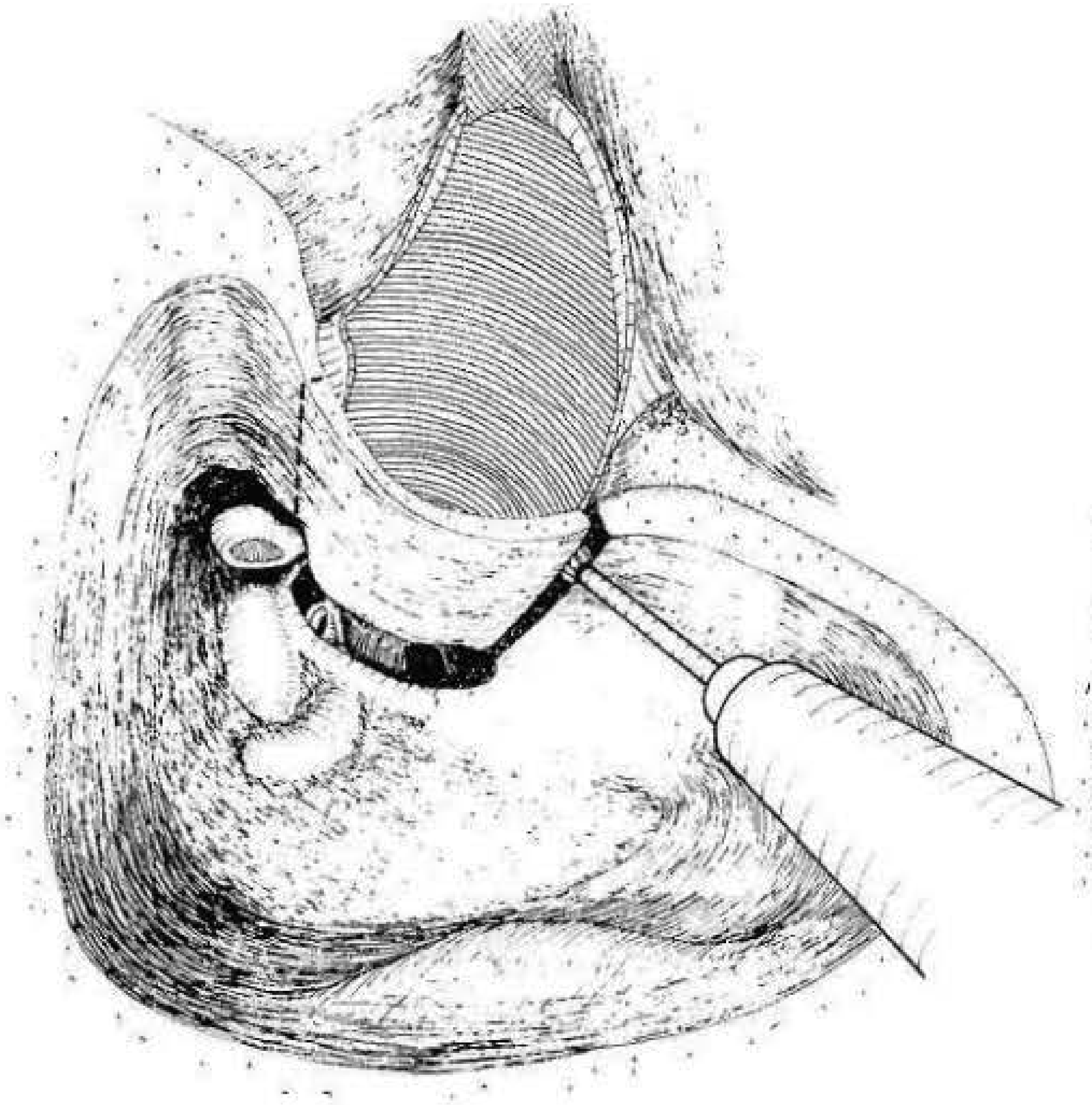


Fig. **513** **Portmann's posterior ear canal wall removal.** After the Portmann's posterosuperior incision in a retroauricular approach and elevation of the posterior ear canal skin with a strip of gauze, a classic intact canal wall mastoidectomy is performed, with atticotympanotomy and removal of the incus and posterior buttress. The inferior osteotomy is performed using a small diamond burr, starting at the bottom of the posterior atticotympanotomy opening. The superior osteotomy is indicated by dashed line, starting at the level of the malleus and proceeding laterally

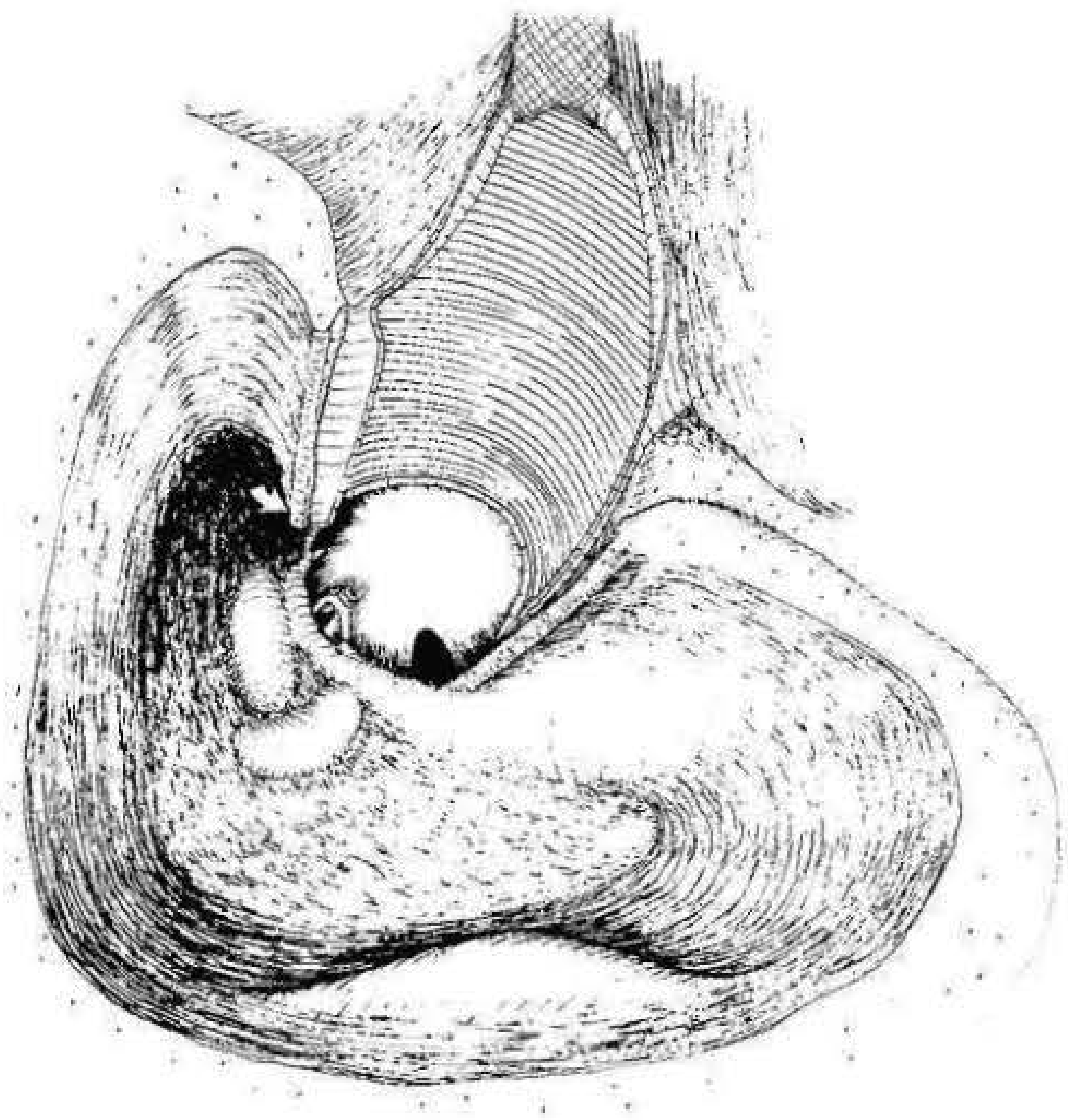


Fig. **514** The posterior bony ear canal wall has been removed, as has the malleus, and a typical conservative radical operation situation is illustrated, with a total perforation but with the stapes present. In the anterior attic, the anterior bony plate has to be removed, and a connection between the epitympanic sinus and the Eustachian tube has to be established medial to the superior bony ear canal (arrow), which is left in place. The view of the hypotympanum is good

After removal of the bony ear canal and the malleus, the closed cavity situation temporarily becomes an open cavity, with excellent exposure of the tympanic cavity (Fig. **514**). However, since the superior osteotomy is rather low, the anterior attic has to be further exposed by carrying out drilling as described for an anterior atticotympanotomy (pp. 122–127) in order to achieve good communication with the Eustachian tube orifice through the epitympanic sinus. After removal of the bony ear canal wall and tilting of the patient in an anterior direction, there is a good opportunity for safe cleaning of the anterior attic and tympanic orifice of the Eustachian tube.

The removed bony ear canal wall is cleared of any cholesteatoma under high-power magnification. After the cholesteatoma removal has been completed, the bony ear canal wall is replaced and fixed (Fig. **515**).

Portmann (1979) probably used Histoacryl glue, which was the only available fixative in the 1970s (Fig. **515**). However, only very small amounts need to be used, preferably on the posterior side of the bony ear canal, with no contact with the ear canal skin. Int the present author's experience, Histoacryl glue creates chronic granulations when in contact with the ear canal skin. Filling the osteotomy grooves with autogenous bone paté or fibrin glue or both, or fixation with Ionomer bone cement, which is now available, is a good alternative after a type II ossiculoplasty and closure of the total perforation with an onlay fascia graft (Fig. **516**), which partly covers the osteotomies. In addition, small pieces of fascia or cartilage can be placed over the osteotomies.

Osteoplastic Meatoantrotomy (Feldmann)

Recognizing the problems of replacement and fixation of the bony ear canal wall in osteoplastic mastoidectomy with a relatively large bony defect,

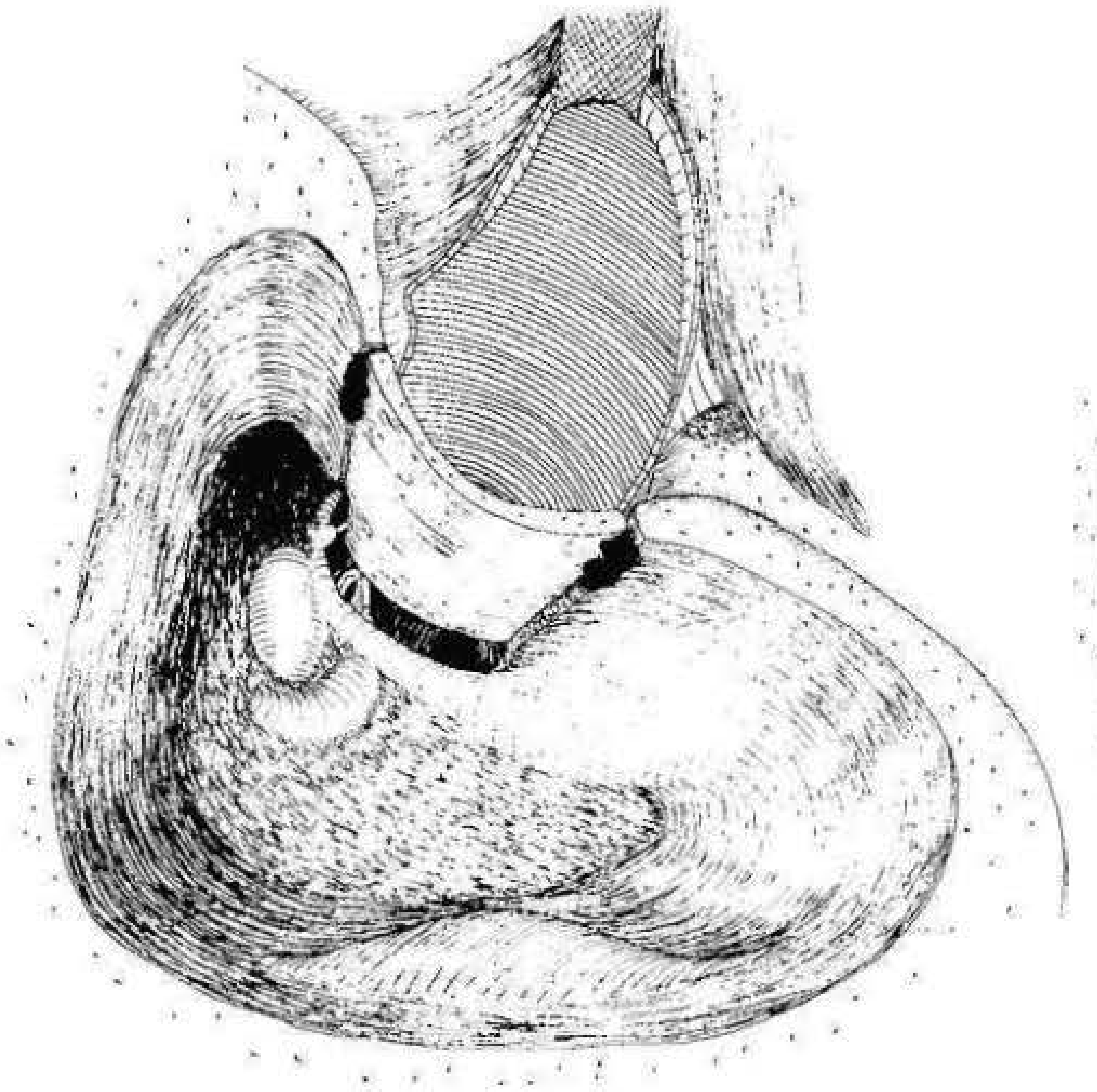


Fig. **515** Repositioning of the bony ear canal wall, and fixation of it to the Zygomatic root and facial ridge, with Histoacryl, or nowadays with lonomer cement (dark spots)

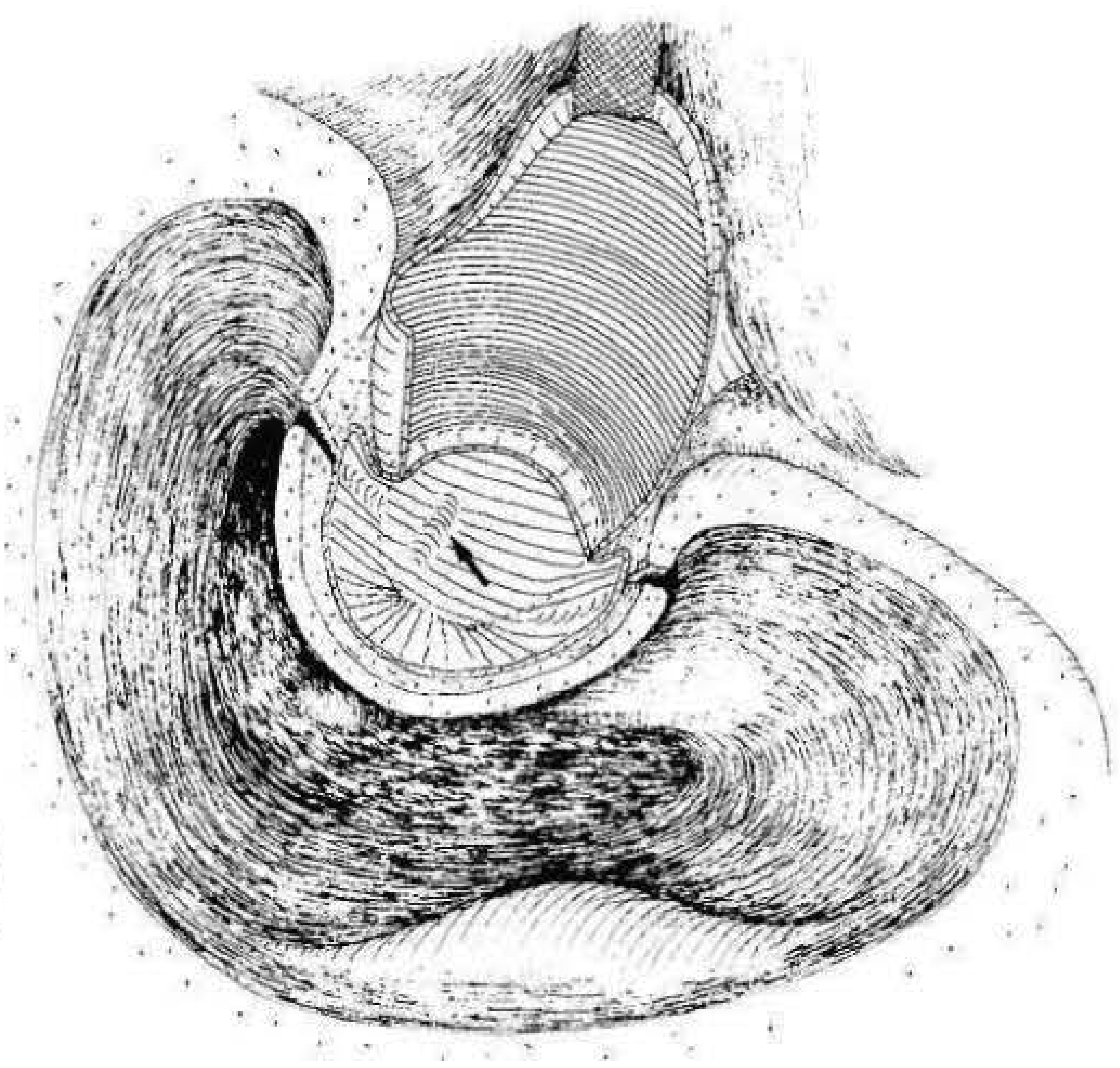


Fig. **516** Transcanal view of the repositioned bony ear canal wall with the osteotomies, a type II tympanoplasty (arrow), and closure of the total perforation with an onlay fascia graft placed on the fibrous annulus and partly covering the osteotomies as well

caused by drilling the osteotomies, Feldmann (1977, 1978) designed a reciprocating saw for osteoplastic microsurgery, consisting of an electromagnetic oscillator driving the saw. The saw is commercially produced by Storz, Tuttlingen, Germany, as the Feldmann micro-oscillating saw (Fig. **517**). Unique to the saw is the way in which the soft tissues are vibrated by the saw, but not cut. There is no risk of damage to the ear canal skin, tympanic membrane, or exposed dura. The ergonomically designed handpiece permits work under the microscope. The sawing amplitude is continously variable from 0 to 3 mm using a foot switch, thus reducing risk of damage in the proximity of sensitive structures such as the stapes and the facial nerve. There are saw blades of different sizes; a thickness of 0.25 mm is used for osteoplastic ear operations (Fig. **517**).

After exposure of the mastoid plane with a retroauricular approach, a lateral circumferential incision is performed between the 12-o'clock and 6-o'clock positions at the level of Henle's spine (Fig. **518**), the ear canal skin is elevated between the 1-o'clock and 6-o'clock positions together with the fibrous annulus, and the posterior part of the tympanic cavity is thus exposed (Fig. **519**). An atticoantrotomy is performed (Fig. **520**), leaving the ear canal wall relatively thick, especially at the

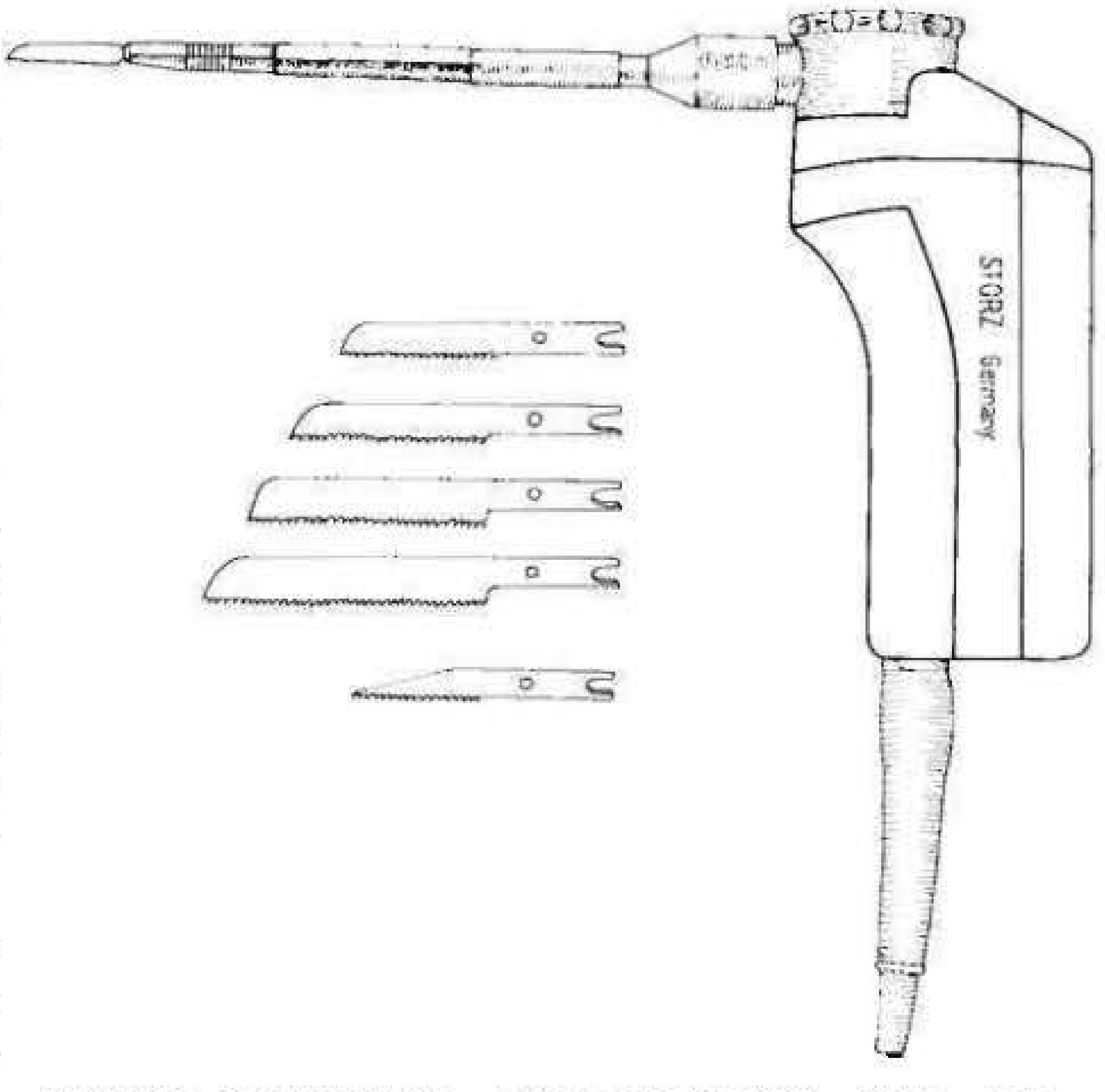


Fig. **517** **Feldmann's micro-oscillating saw,** produced by Storz, Tuttlingen, Germany, showing saw blades of various lengths and shapes

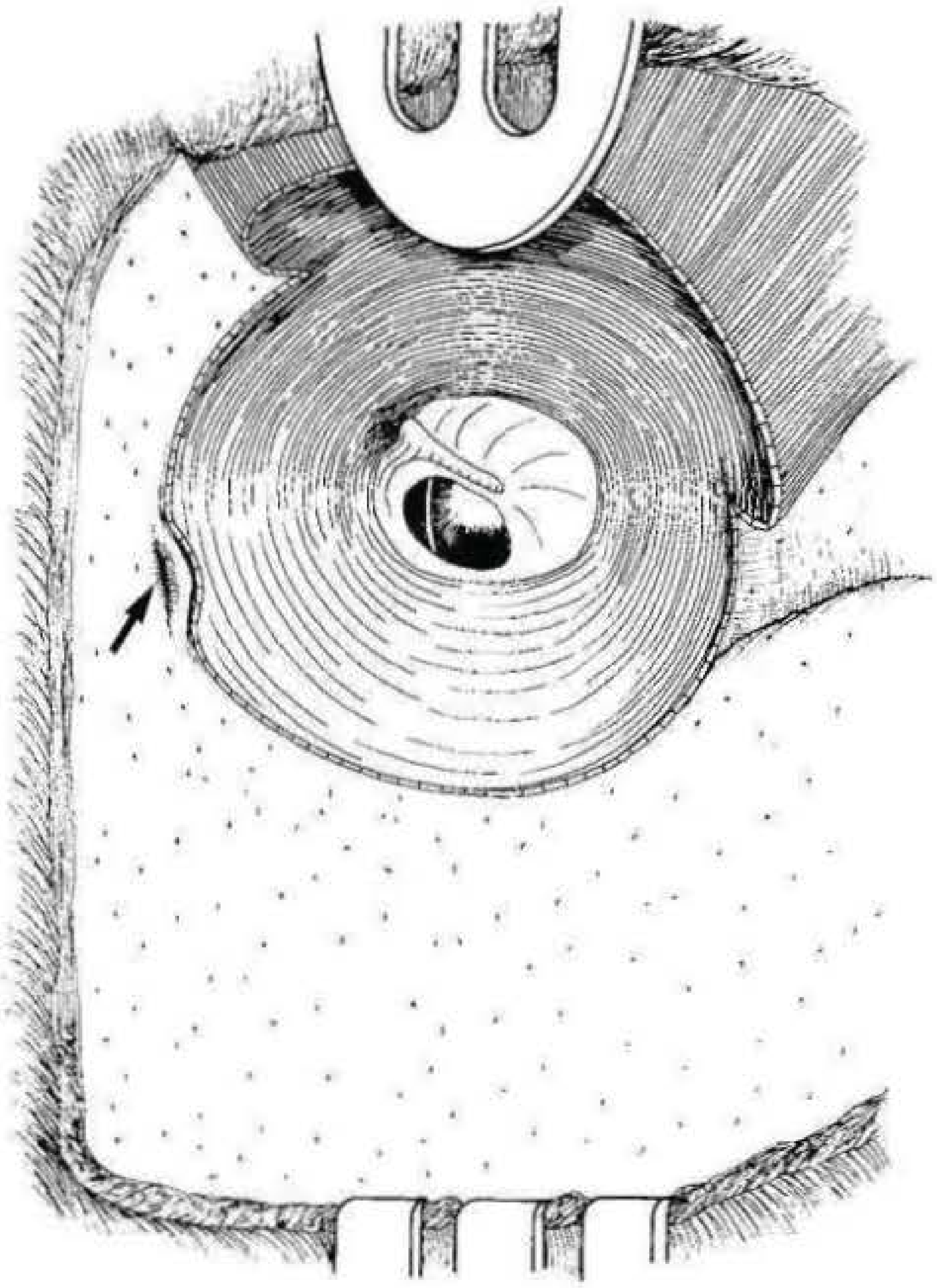


Fig. **518** **Feldmann's osteoplastic meatoantrotomy.** In a case with a posterior perforation, a retroauricular approach with exposure of the mastoid plain is carried out. The ear canal is opened with a circumferential incision from the 12-o'clock to the 6-o'clock positions at the level of Henle's spine (arrow)

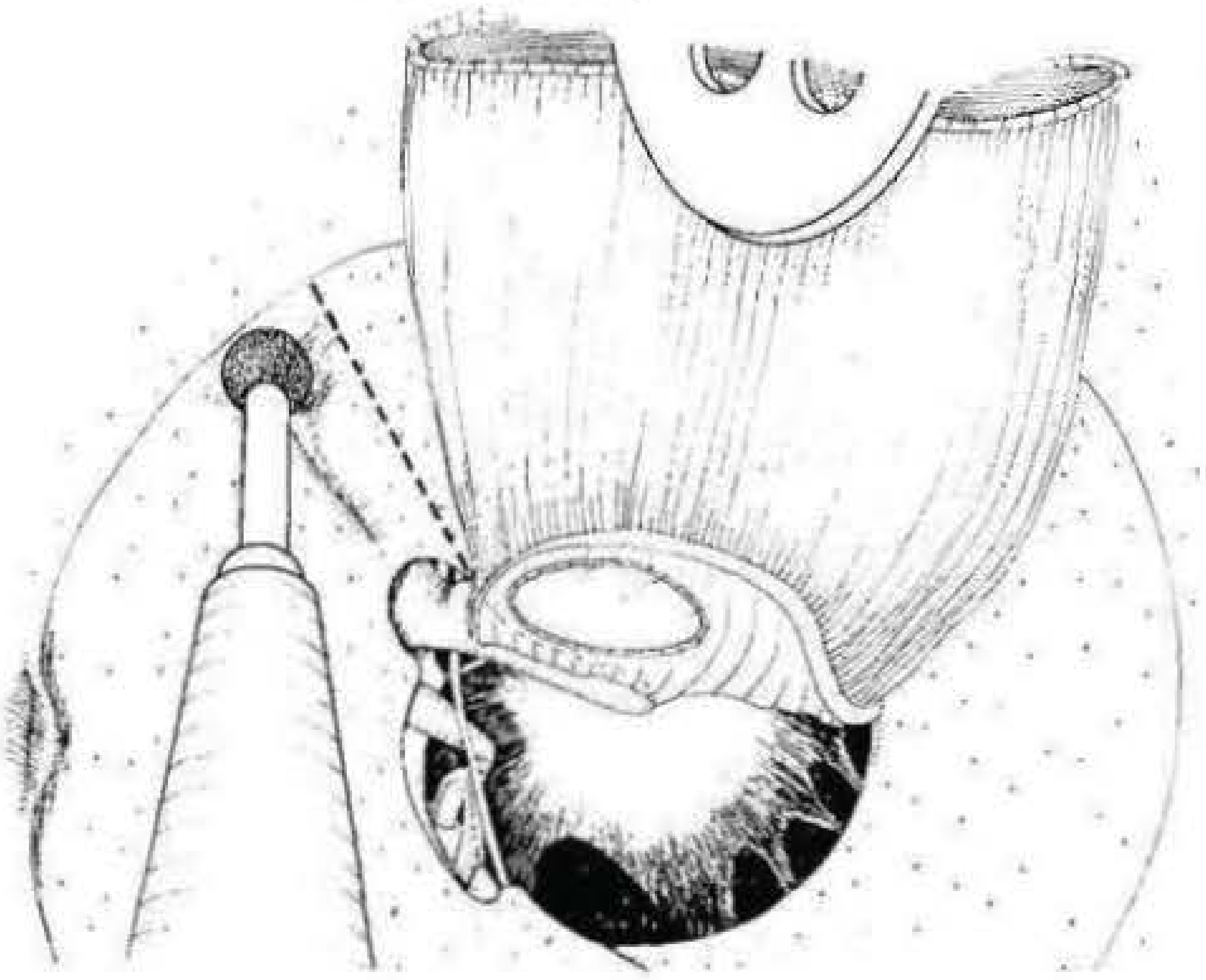


Fig. **519** The ear canal skin is elevated together with the fibrous annulus and drum remnant, exposing the posterior tympanum. The irregularities around the tympanosquamous suture on the superior wall are drilled away. The position of the superior osteotomy is indicated by a dashed line

osteotomy sites, inferiorly and superiorly. The short process of the incus and the articulation between the incus body and the malleus head are located, leaving the lateral attic wall intact. The tegmen antri and tegmen tympani are also located. It is important that the bony ear canal wall, including the lateral attic wall, is not too thin, so as to be able to perform the special cuts with the microsaw properly.

The tympanosquamous suture has already been smoothed (Fig. **519**) in order to place the microsaw onto the meatal side and perform the superior osteotomy.

A standard posterior atticotympanotomy is not necessary. It is sufficient to drill a hole into the facial recess just below the end of the short process of the incus (Fig. **520**). Four cuts with the Feldmann oscillating microsaw are made.

The first cut starts at the anterior border of the atticotomy drilling (Fig. **520**), and runs parallel to the tegmen tympani and mastoid tegmen. Damage to the dura is almost impossible, since the direction of the drilling is parallel to the mastoid tegmen. If the middle fossa dura is exposed by the saw, some bleeding will occur.

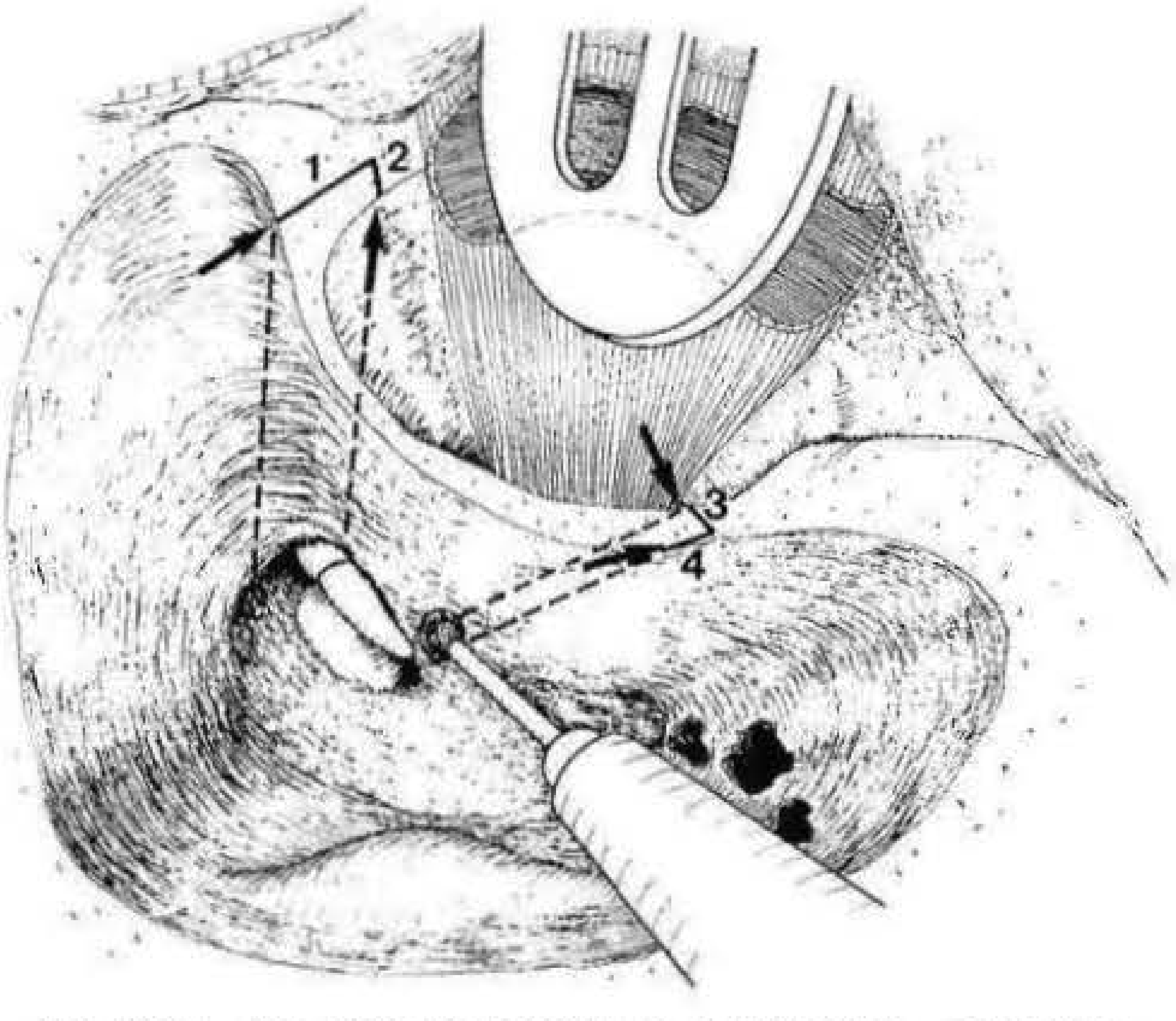


Fig. **520** An atticoantrotomy is performed, exposing the incus and the junction between the incus and the malleus head. Beneath the end of the short process of the incus, a hole is drilled through the facial recess with a small diamond burr. Cuts 1 and 2 for the superior osteotomy are indicated by thick lines laterally and dashed lines medially and the directions of cuts 1 and 2 are indicated by the arrows. The direction of the inferior osteotomy from the hole in the facial recess parallel to the facial ridge is indicated by dashed lines, and the anteroposterior direction of cuts 3 and 4 is indicated by the arrows

The second cut starts in the ear canal just superior to the short process of the malleus (Fig. **519**). The saw should not touch the malleus head. The cutting goes through the entire lateral attic wall and meets the first cut at an angle of 80-90°. It is possible to recognize when the second cut has reached the level of the first cut.

The third cut starts in the ear canal, parallel to the course of the facial ridge, at the level of the hole made previously through the facial recess, i. e.. at about the 9-o'clock position (Fig. **520**). With a hook pushed through the hole from the mastoid side, the medial placement of the saw in relation to the facial nerve can be recognized on the tympanic side (Fig. **520**).

The fourth cut starts in the mastoid cavity (Fig. **520**). The saw is placed in the hole in the facial recess, and follows the direction of the facial ridge toward the level of the third cut in the lateral edge of the ear canal. The mediolateral direction of the fourth cut is exactly the same as that of the third cut, and there is no risk of damage to the facial nerve.

The bony ear canal wall is easily removed when all the cuts have been performed correctly; otherwise, sites with inadequate cuts are found and further cuts performed. Before removal of the ear canal wall, any remaining adhesions between the medial edge of the canal and the ossicular chain are torn with a hook.

After removal of the ear canal wall, the cholesteatoma can easily be removed (Fig. **521**), and the bony ear canal wall is carefully cleared of cholesteatoma and granulations, and can later be replaced.

If the medial part of the bony ear canal wall has been resorbed, or has to be drilled away because of extensive involvement with cholesteatoma, the shorter ear canal is placed more medially after some adjustments by drilling the edges (Fig. **522**).

Reposition of the bony ear canal wall is relatively easy, because the canal wall should fit exactly into the specially-made grooves (Figs. **520–522**), and should remain stable within those grooves.

After ossculoplasty and underlay fascia grafting of the perforation, the intact ear canal skin is replaced, covering the grooves. Today, the ear canal wall can be fixed with Ionomer cement, as suggested by Babighian (1992 a, 1992 b), and the grooves covered with bone paté.

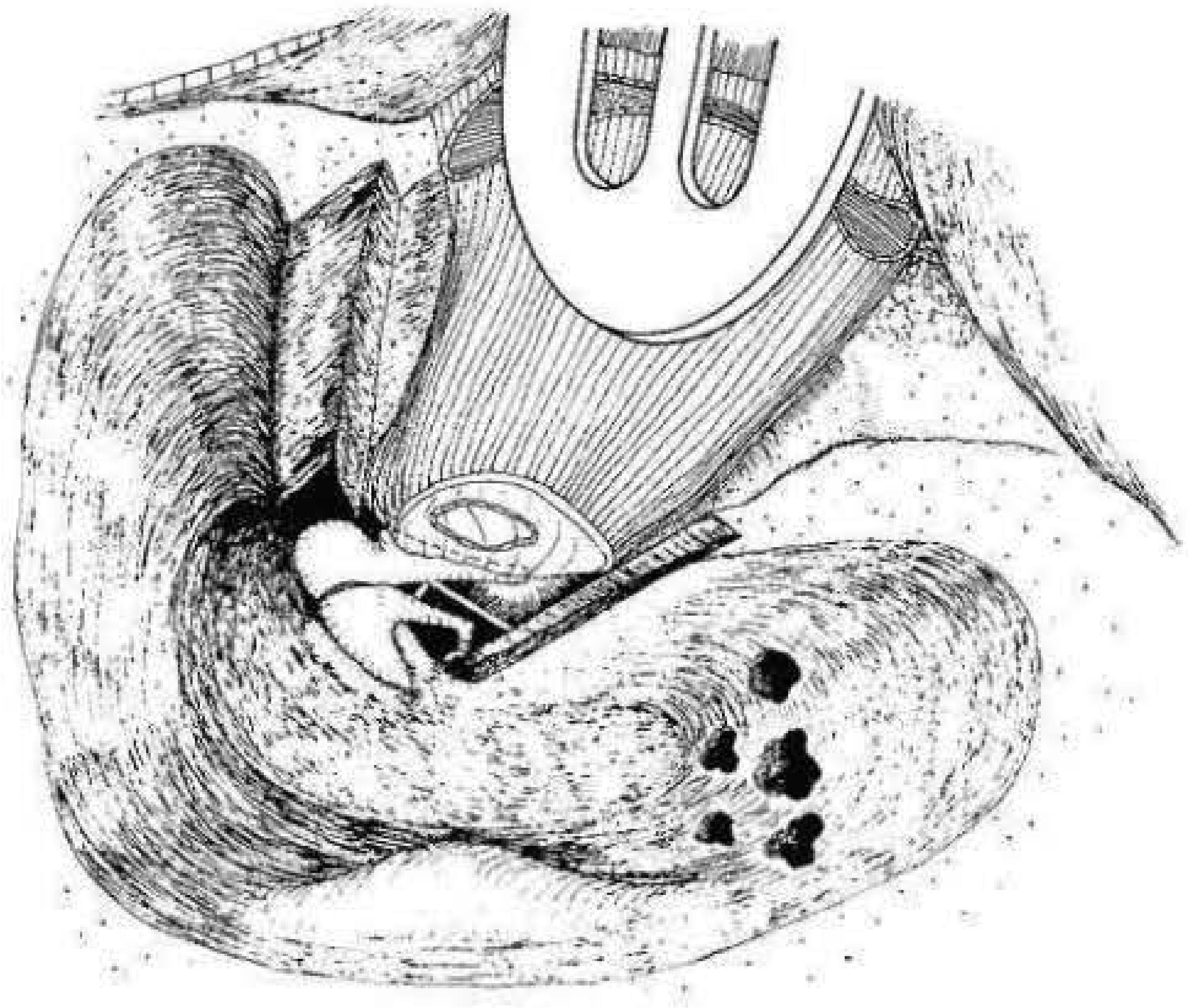


Fig. **521** Situation after removal of the bony ear canal wall in Feldmann's osteoplastic meatoantrotomy. The direction of cutting in superior tympanotomy is indicated. The deepest point in the groove is shown by arrows. The V-shaped groove in inferior osteotomy is well illustrated, making the reposition of the ear canal easy. The exposure of the tympanic cavity and the attic with the ossicular chain is good

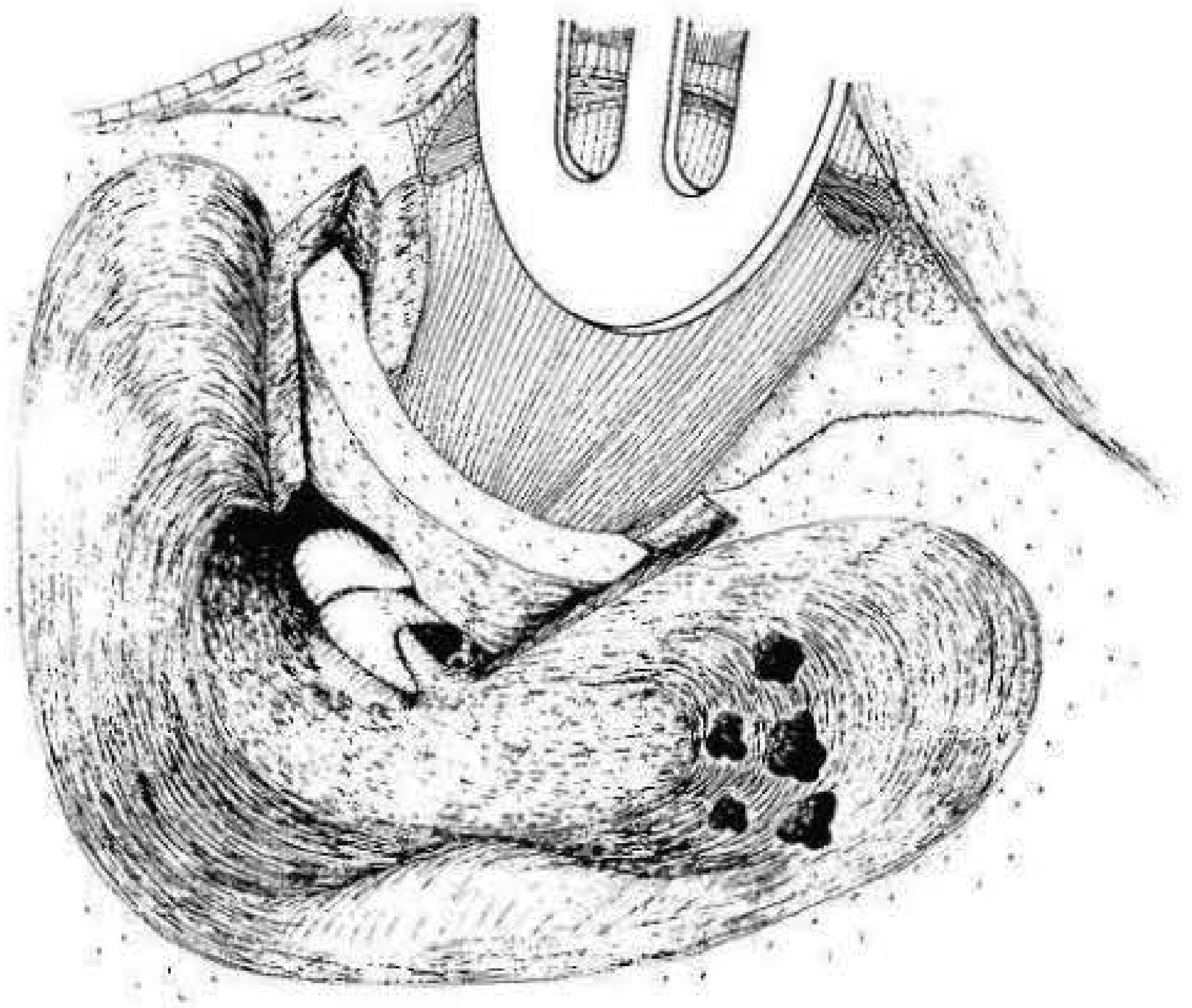


Fig. **522** The shortened bony ear canal wall is placed medially, after some adaptation of its size, to bridge the significant defects in the lateral attic wall. There is no bone at the lateral 2-3 mm of the bony ear canal, which is of minor importance

Obliteration in Temporary Bony Ear Canal Wall Removal

Mercke (1987) combines Feldmann's technique of temporary bony ear canal removal with firm obliteration of the mastoid cavity and the attic. A large retroauricular incision is performed, and a large, anteriorly based musculoperiosteal Palva flap is prepared. The middle ear is explored, and the extent of the cholesteatoma determined. The intact canal wall mastoidectomy is performed, and the epitympanic space is totally exenterated. After superior and inferior osteotomies with the Feldmann microsaw, the bony ear canal wall is temporarily removed and cleaned. The cavity is safely cleared of all cholesteatoma, and all the structures in the tympanic cavity are removed. The radical cavity is then immediately reconstructed by reinserting the bony meatal wall into its original position, and in addition it is extended medially using bone chips, so that the middle ear becomes completely closed off from the epitympanic space (Fig. **523**). Silastic is placed in the middle ear cavity, and the drum is reconstructed with fascia (Fig. **524**). The mastoid cavity is obliterated using bone chips and autogenous bone paté taken from the mastoid cortex. Finally, the musculoperiosteal flap is placed in the most lateral parts of the mastoid cavity and epitympanic space.

A second-look procedure with ossiculoplasty is performed after one year. Residual cholesteatoma was found in 5% of ears, but no recurrent cholesteatoma. Mercke believes that this technique is much better in his hands than the classic combined-approach tympanoplasty, which has rates of 21% recurrent cholesteatoma and 25% residual cholesteatoma. Potential cholesteatoma due to retraction was found in 16% of ears. (Mercke 1986).

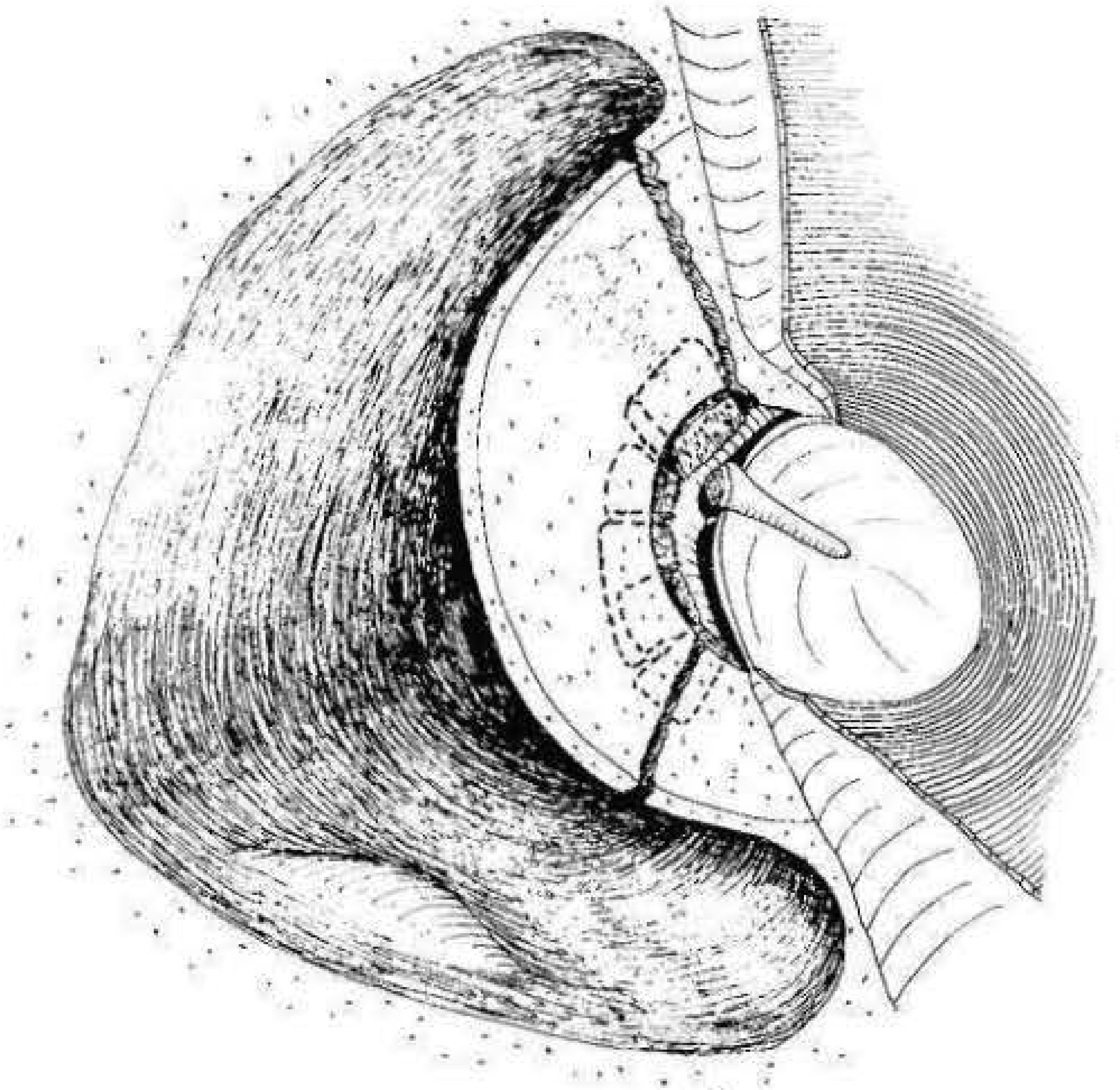


Fig. **523** **Temporary removal of the bony ear canal wall with complete obliteration of the mastoid cavity (Mercke).** After repositioning the bony ear canal wall in an attic cholesteatoma with intact pars tensa situation, and prolongation of the bony ear canal wall with pieces of bone placed on the prominence of the facial nerve and the lateral semicircular canal, the attic and aditus ad antrum are solidly obliterated with pieces of bone and bone paste. Complete separation of the tympanic cavity from the attic is carried out

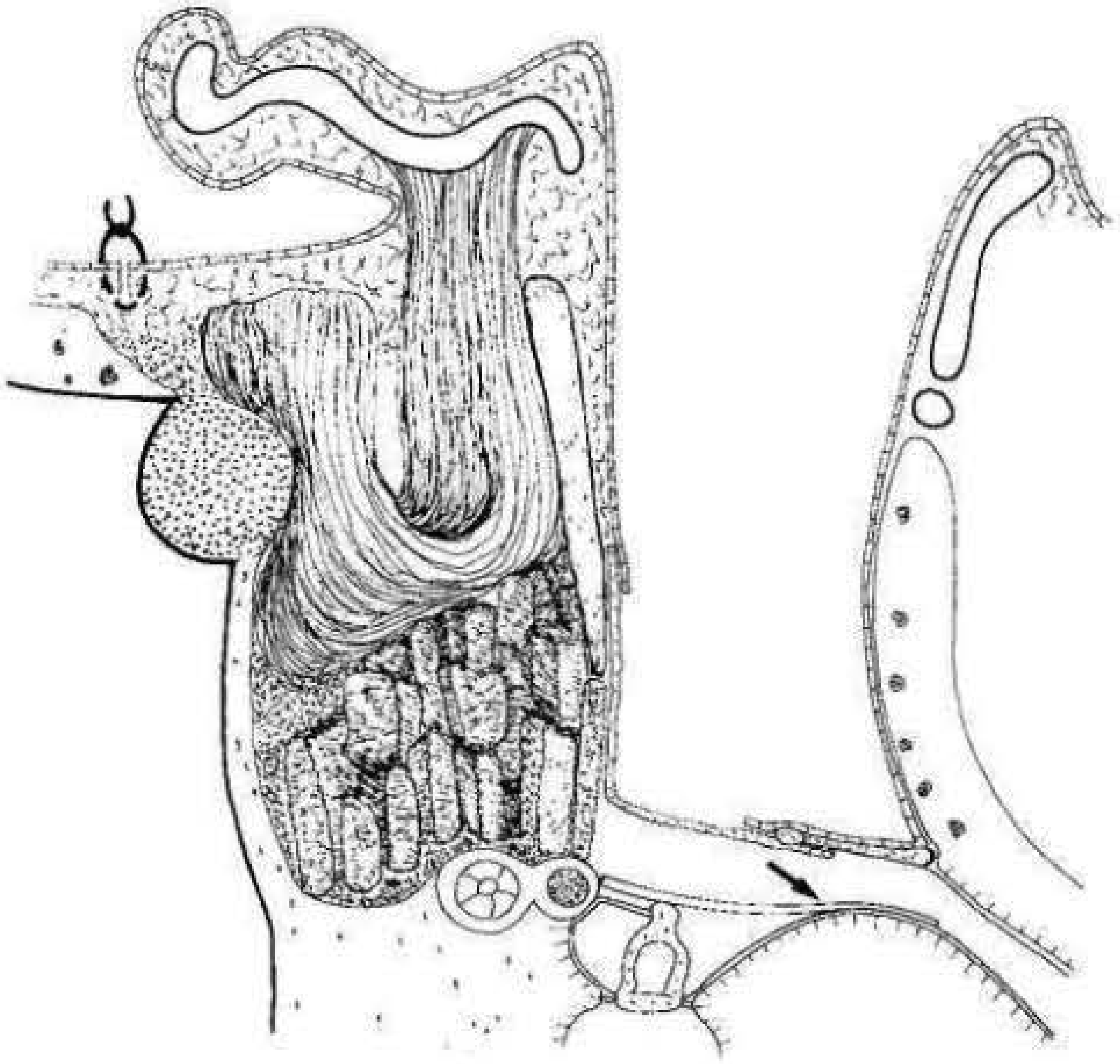


Fig. **524** Side view of Mercke's complete obliteration. The attic, aditus ad antrum, and medial part of the mastoid cavity are filled with bone chips and bone paste behind the repositioned bony ear canal wall. The lateral part of the cavity and the epitympanic space are filled with a large Palva flap. Fascia is placed as an underlay graft. The ossiculoplasty will be performed at the second stage. A thin piece of Silastic is placed on the medial wall of the tympanic cavity (arrow), and will be removed at the second-stage operation

The Babighian Posterior and Attic Wall Osteoplasty

The Babighian technique (1992 a, 1992 b) combines the Wullstein osteoplastic epitympanotomy and the Feldmann meatoantrotomy techniques. Its principle is to remove the entire ear canal wall, if necessary, and especially its most anterior part, covering the protympanum and sinus epitympanum as well as the anterior attic, which is necessary in case of attic cholesteatoma (Fig. **525**). If desired, the posterior wall can be temporarily removed inferiorly for instance in sinus cholesteatoma, glomus tumors, or facial nerve neuroma. The other innovation is the firm fixation of the replaced ear canal wall using lonomer cement (Ionos, Seefeld, Germany).

Babighian (1992 a, 1992 b) uses an extended endaural approach elevating the canal skin between the 3-o'clock and 5-o'clock positions. A posterior tympanotomy is performed, and the typanomeatal flap is elevated, exposing the posterior tympanum and the ossicular chain (Fig. **526**). An anterior tympanotomy is also performed, exposing the anterior bony annulus from the malleus neck at the 12-o'clock position around to the 3-o'clock position.

The tympanosquamous suture and the bony irregularities around it are removed, and the superior bony car canal is enlarged superiorly. Using a very small diamond burr, the anterior contour of the attic wall to be resected is outlined, corresponding to the protympanic recess and, more superiorly, to the epitympanic sinus and supratubal recess. By drilling the meatal side of the bony ear canal anterosuperiorly, the tympanosquamous suture between the tympanic bone and the squamous bone becomes evident. This suture identifies the site of the superior cut (Fig. **527**).

The superior cut is then completed medially using Feldmann's microsaw directed caudally along the tegmen tympani to the posterosuperior border of the external meatus (Fig. **528**). Finally, the superior cut is completed laterally (Figs. **529, 530**). The site of the inferior cut depends upon the pathology to be removed (Fig. **525**). Sometimes it is placed on the floor of the tympanic cavity.

In cases with attic cholesteatoma and limited pneumatization, it is sometimes difficult to perform the superior cut, and in these cases it is wise to enlarge the ear canal by drilling as far as the mastoid tegmen and temporarily remove only a part of the ear canal wall, e. g., the lateral wall of the attic. The exact placement of Feldmann's microsaw also depends on the side being operated on. When removing the ear canal on the right ear, it is better to

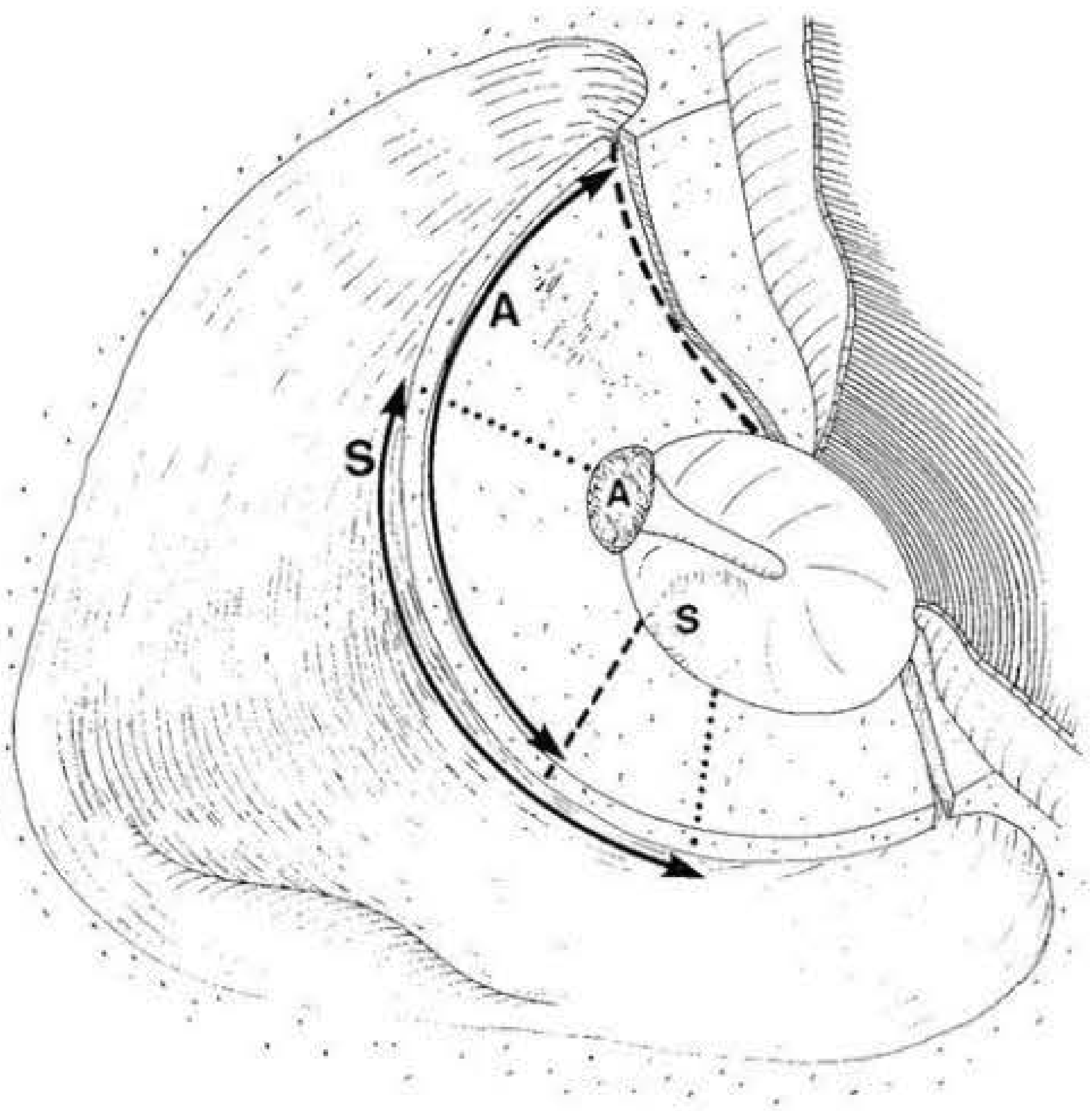


Fig. **525** **Babighian's posterior and attic wall osteoplasty.** Maximal extension of the temporary ear canal wall removal from the 3-o'clock to the 6-o'clock positions. Extension for temporary bony ear canal wall removal in (A) attic cholesteatoma (between the 3-o'clock and 9-o'clock positions) and (S) sinus cholesteatoma (between the 12-o'clock and 8-o'clock positions)

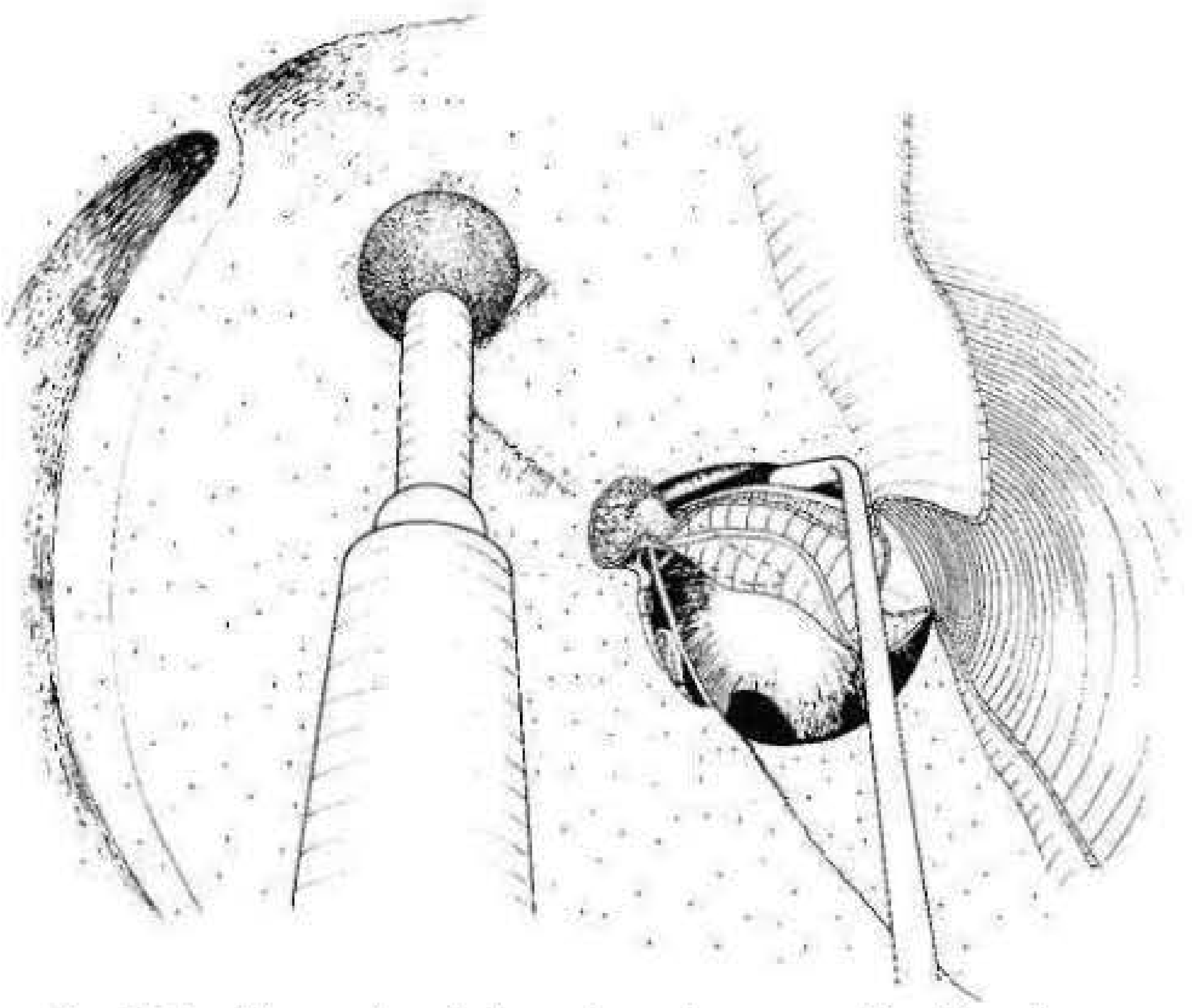


Fig. **526** The extended endaural approach with elevation of the ear canal skin and drilling of the superior ear canal wall. An anterior tympanotomy is performed, exposing the anterior bony annulus between the 12-o'clock and 3-o'clock positions localizing the eminence of the tensor tympani muscle. A mastoidectomy is performed behind the intact ear canal wall

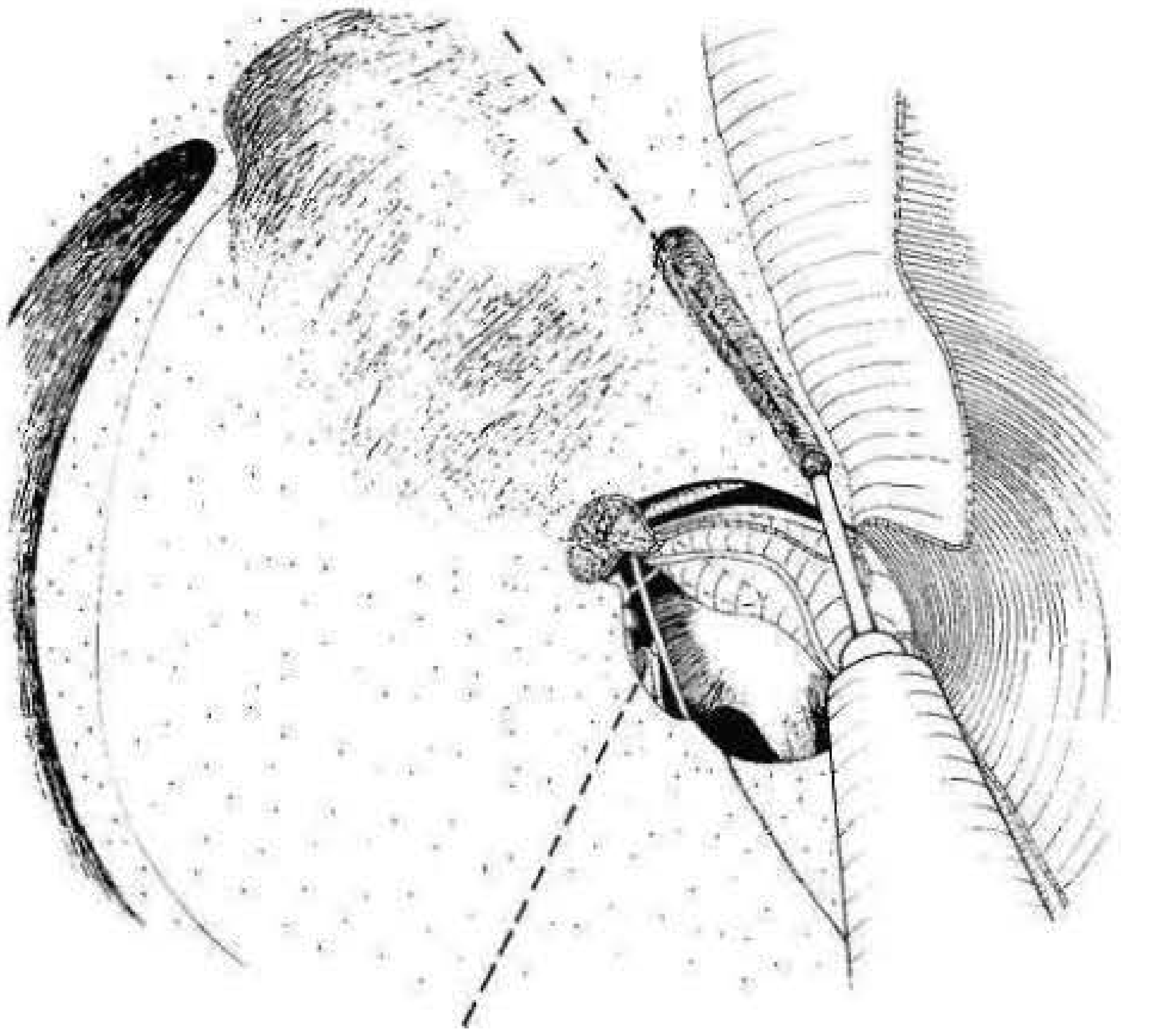


Fig. **527** After further drilling of the superior ear canal wall, a groove is outlined with a small diamond burr to facilitate the most anterior placement of the Feldmann's saw. The direction of the superior and inferior osteotomies are indicated by dashed lines

drill transmeatally with microsaw, starting in the groove anteriorly at the tympanosquamous suture and continuing in a superior and lateral direction (Figs. **528, 529**). When doing the superior cut on the left ear, it is better to start within the mastoid cavity and continue along the tegmen tympani.

After performing the superior and inferior cuts (Fig. **530**), the bony ear canal wall is mobilized, and can be carefully removed together with the cholesteatoma attached to its medial aspect. By elevating the cholesteatoma membrane together with the freed ear canal wall, the incus and resected malleus head, and the superior part of the drum, the cholesteatoma is removed en bloc (Fig. **531**). The removed ear canal wall is carefully cleaned and after ossiculoplasty and fascia underlay grafting have been carried out, the bony ear canal wall is replaced in the same position and fixed with Ionomer cement. In order to avoid contact with the ear canal skin, the cement is placed on the posterior aspect of the ear canal both at the superior and inferior osteotomies (Fig. **532**).

Babighian (1992 a, 1992 b) operated on 52 patients using this promising method. The indications included cholesteatoma, extensive tympanosclerosis, facial nerve neuroma, glomus tympanicum tumor, and cochlear implant revision surgery. The present author believes that this method represents

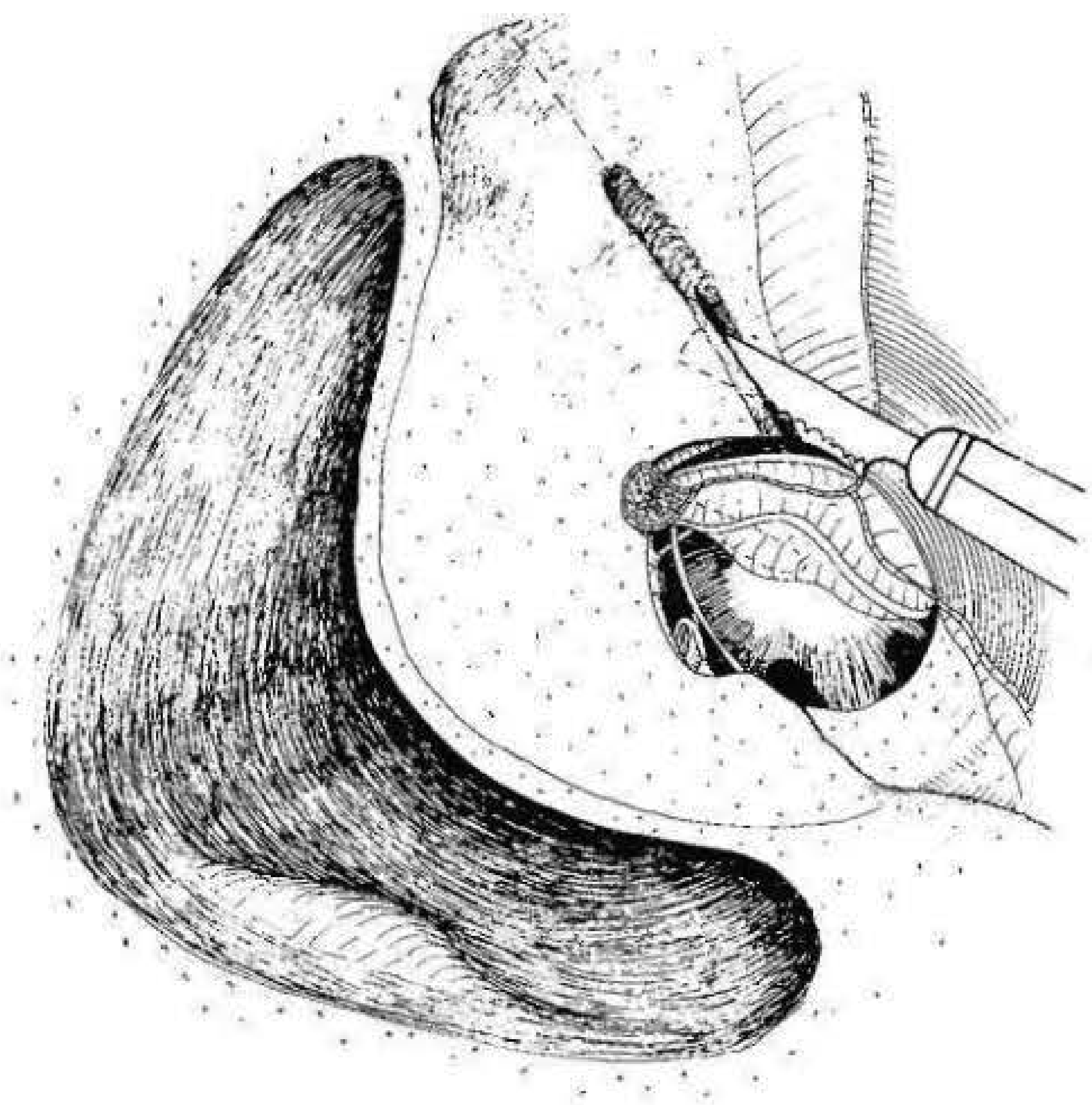


Fig. **528** The most anterior and medial parts of the ear canal are cut with a Feldmann's saw, following the outlined groove. The cutting continues in superior and lateral directions

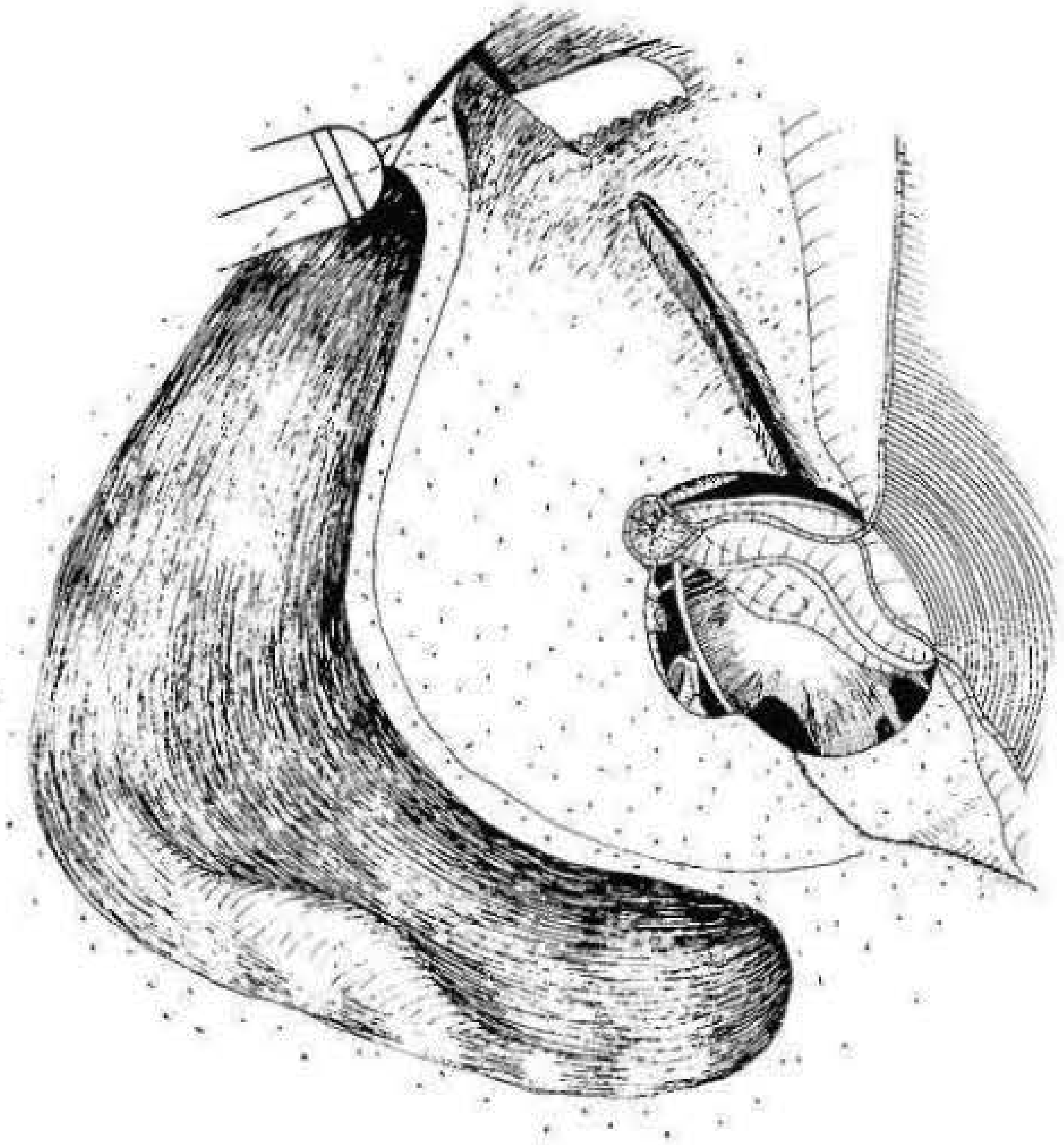


Fig. **529** Cutting with Feldmann's saw is performed along the mastoid tegmen, meeting the anterior cut. The superior cut is not a straight line, and has to be adapted to the space available and the pneumatization a real improvement in the techniques of cholesteatoma surgery, especially in attic cholesteatoma where the main problem is residual disease in the anterior attic, since in this method the removal of the most anterior part of the bony ear canal wall provides excellent exposure of the attic and the protympanum.

The method is similar in some respects to the author's modificaton of the intact canal wall technique, where extra effort is also made to visualize the anterior attic and preserve a thin bony bridge for reconstruction.

With Feldmann's microsaw (1977, 1978), the cuts are smaller than with a burr. In the author's opinion, the displacement method, especially Richards' mobile bridge technique, as well as the Babighian technique, should be applied more often in attic and sinus cholesteatoma. After the bony ear canal wall has been pushed inferiorly or removed, the attic region is excellently exposed in a postauricular approach, and there is no need for additional endaural surgery in cases with an intact pars tensa. The same is true in sinus cholesteatoma with good exposure of the posterosuperior region of the tympanic cavity. In tensa retraction cholesteatoma, the techniques of temporary removal of the bony ear canal wall are the best methods.

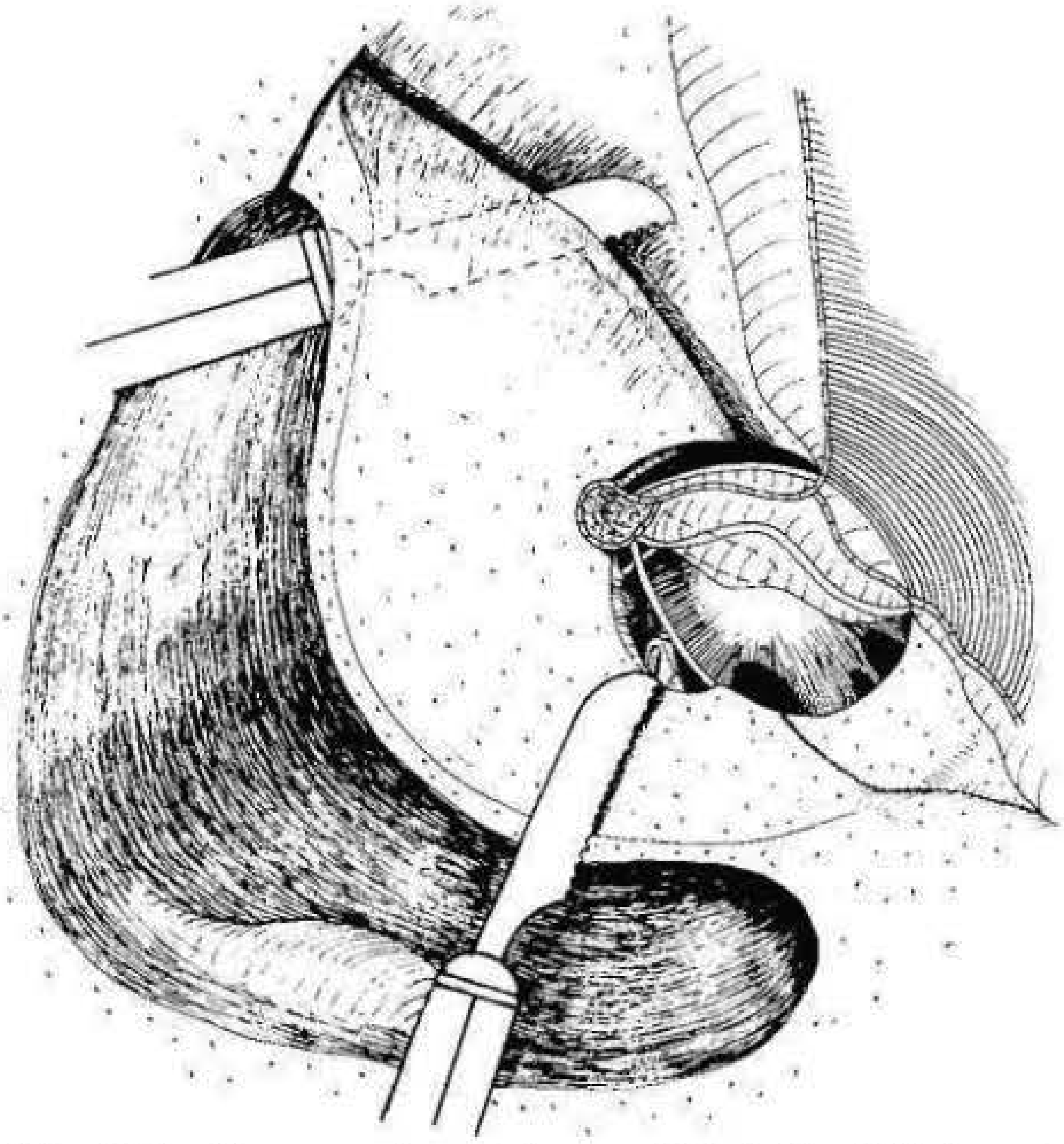


Fig. **530** The superior cut is completed. The inferior cut at the 9-o'clock position is performed by placing the Feldmann's saw on the meatal side of the ear canal

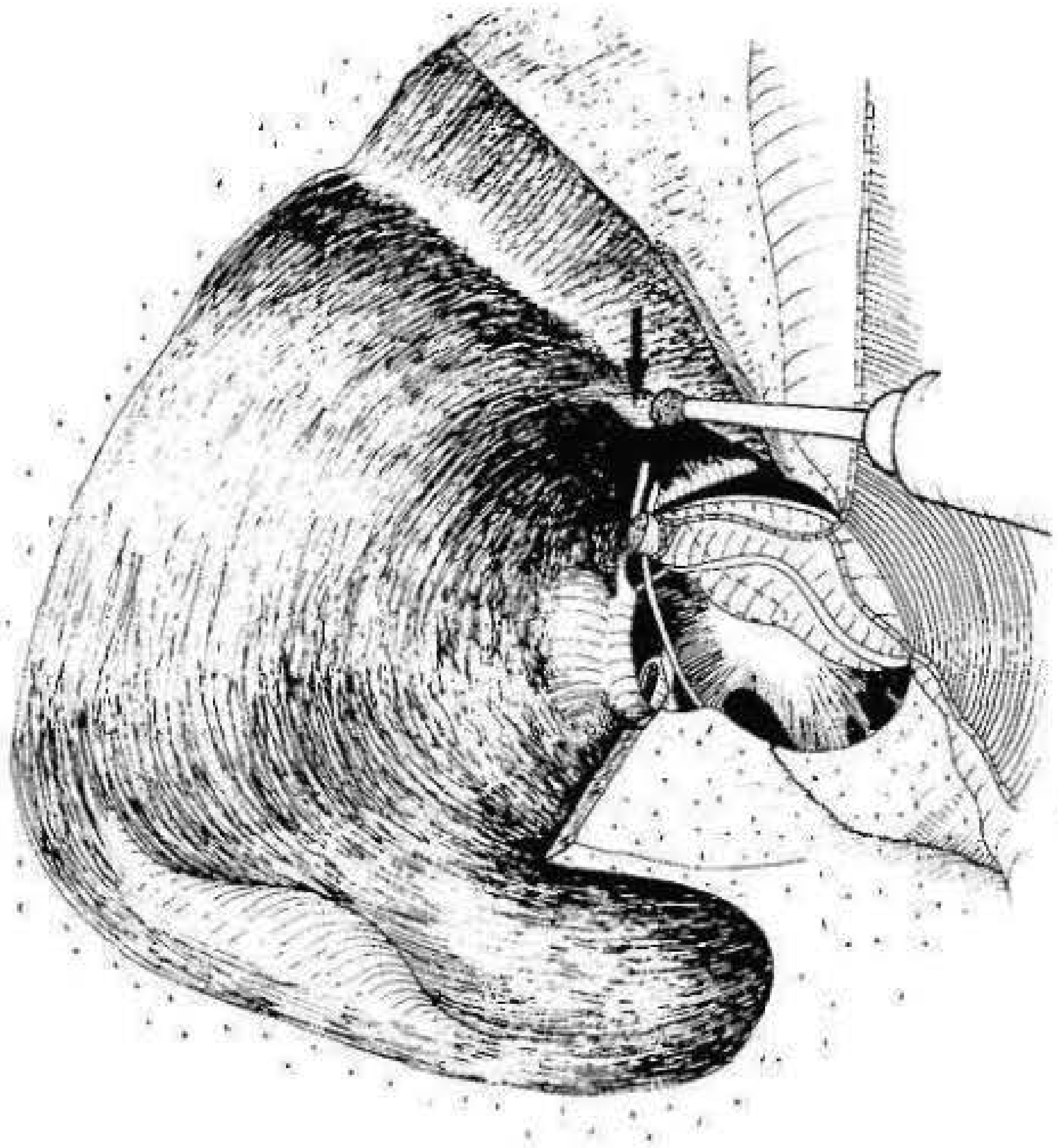


Fig. **531** The ear canal wall has been removed, and the mastoid cavity is cleaned, the malleus head is resected, and the anterior attic plate (arrow) is drilled away, establishing a good connection to the epitympanic sinus

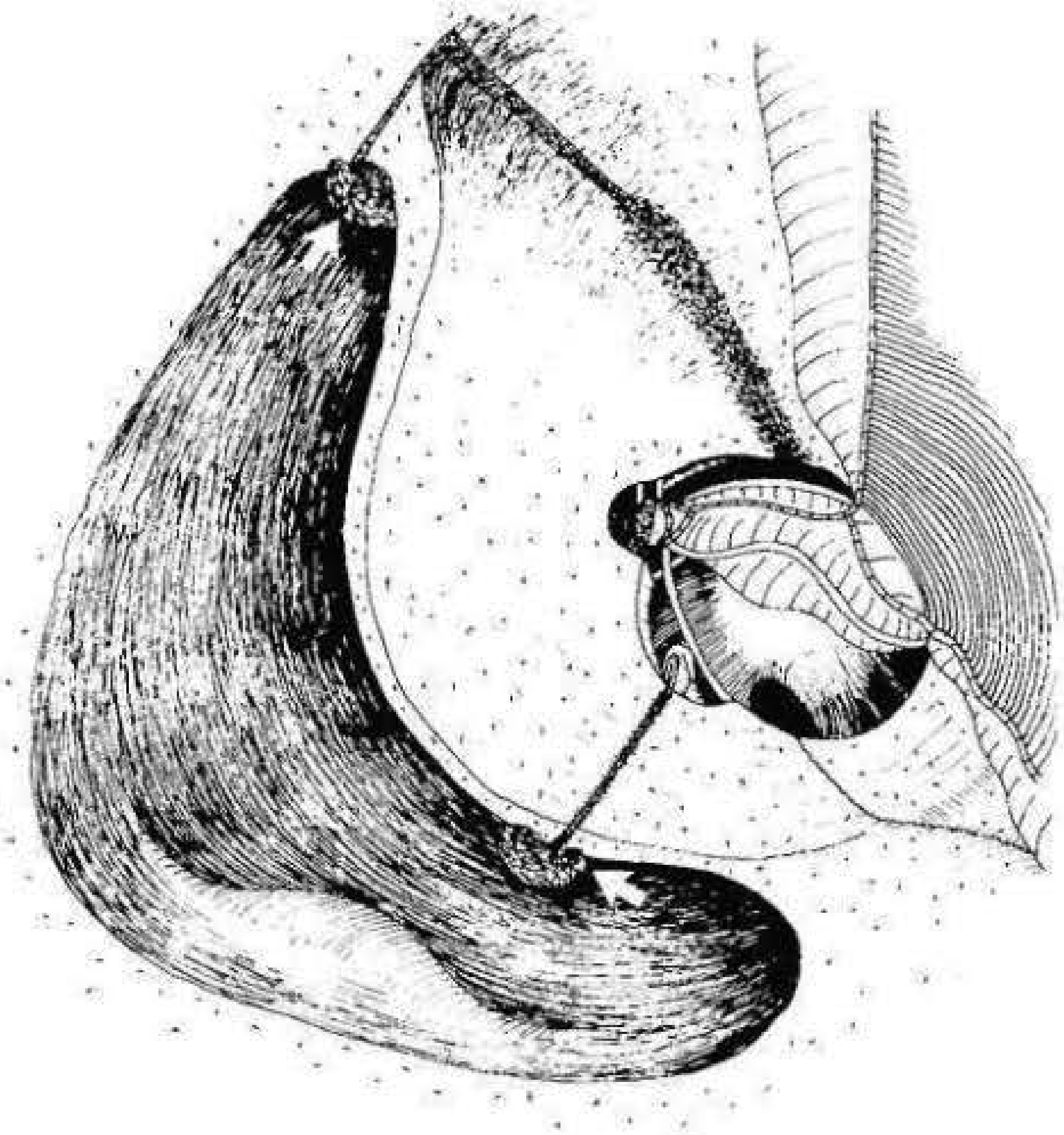


Fig. **532** The ear canal wall is in place. It is fixed superiorly and inferioriy with lonomer cement, and the grooves are covered with bone paté

9 Tympanomeatoplasty with Preservation of the Bony Bridge (Wigand)

Wigand's technique (Wigand 1967, 1978), also called transcanal mastoidectomy, is based on the principle of restoring an aerated antrum (Wigand 1970), and is a third solution in cholesteatoma surgery when attempting to reventilate the mastoid cavity. The technique is neither a canal wall–up nor a canal wall–down technique, but includes elements of both techniques, i. e.: **a**) The preservation of as much of the bony ear canal as possible, leaving at least a small bridge (Fig. **533**), and subsequent total reconstruction of the ear canal in order to reventilate the cavity. As antrotomy and atticotomy are performed behind the preserved bridge, this method resembles a canal wall–up technique. **b**) The transmeatal removal of as much of the bony ear canal wall as necessary, so that, in extreme cases, a transmeatal atticoantrotomy with a preserved but displaced bridge is the result, which then resembles a canal wall–down procedure. However, the ear canal and the attic are then reconstructed in order to repneumatize the atticoantrotomy cavity.

The technique gives considerable scope for variation, depending upon the pathology, ranging from a very small atticoantrotomy in cases with minimal pathology to an extensive atticoantrotomy (Fig. **533**), similar to the conservative operation with a preserved bridge.

The Wigand Technique

Initially Wigand (1967), influenced by Wullstein's antrotomy, used a retroauricular approach, but later he changed to an endaural approach, i. e., to a modified Heermann II incision or, as he prefers to call it, the Botey incision, as previously described in 1898 by Botey. An intercartilaginous incision is made at the 12-o'clock position, starting medially about 4 mm lateral to Shrapnell's membrane, and continuing laterally as a very short vertical incision only 1 cm lateral to the meatus in front of the helix (Fig. **534**). From the 12-o'clock position, a lateral circumferential incision is performed at the level of the suprameatal spine all the way around the posterior meatal wall as far as the 6-o'clock position. A second circumferential incision is placed parallel to the first, about 4 mm lateral to the annulus, from the 12-o'clock to 6-o'clock positions continuing a small distance anterolaterally. A large, inferiorly based ear canal skin flap, the Stacke II flap, is elevated and pushed aside, exposing the entire posterior bony ear canal wall. Smaller inferior and superior tympanomeatal flaps are elevated medially, providing a

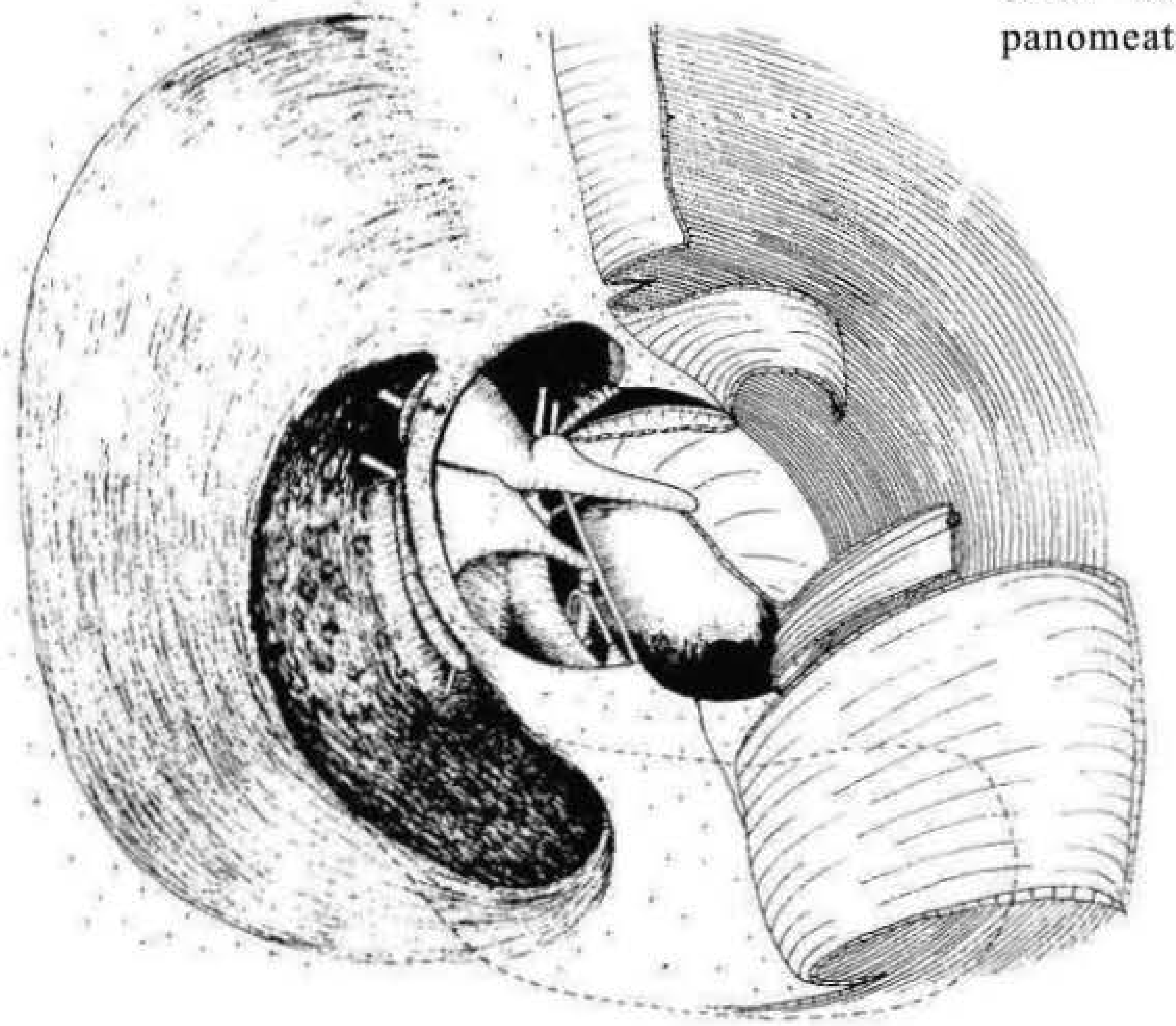


Fig. **533 Tympanomeatoplasty with preservation of the bony bridge (Wigand).** Example of extensive removal of the bony ear canal wall, apart from a small displaced bridge. A large atticoantrotomy is performed, and only a small, superolaterally displaced bridge is preserved (arrow) in a situation with posterior perforation and an intact ossicular chain. This situation resembles a canal wall–down technique, i. e., a transmeatal atticoantrotomy with preserved bridge good view of the posterior tympanum (Fig. **535**). Periosteum is harvested from the exposed mastoid cortex, around the suprameatal spine.

The drilling commences, using a sharp cutting burr, enlarging the ear canal by about 2 mm in its entire posterior circumference (Fig. **535**). Similar enlargement of the ear canal has been used by Brunar in his intact canal wall mastoidectomy (Fig. **261**) (Brunar 1958, 1959), showing that the bony ear canal can remain intact even if it is posteriorly displaced by about 2 mm with transmeatal drilling.

It is easy to enlarge the entire ear canal through the transmeatal route (Fig. **535**), and a small atticotomy can be performed by removing some of the bony annulus. With further drilling, the atticotomy can be extended posterosuperiorly, to the incus body or malleus head. Transmeatal antrotomy or even mastoidectomy can be performed by the transmeatal route (Fig. **536**).

The transmeatal drilling continues, with the bone being removed along the tympanosquamous suture. Although widening of the ear canal by 2 mm still results in an intact ear canal wall, the bony bridge will be displaced superolaterally if the widening is performed at the level of the annulus (Fig. **537**). Further widening of the bony ear canal results in an antrum opening, and an antrotomy behind the bony bridge may be performed and further enlarged, if necessary (Fig. **538**).

The bony annulus is then drilled away between the 2-o'clock and 9-o'clock positions (Fig. **537**), exposing a part of the anterior attic, the malleolar ligament, and posteriorly, the stapes, the horizontal part of the facial nerve, and the facial sinus, with the

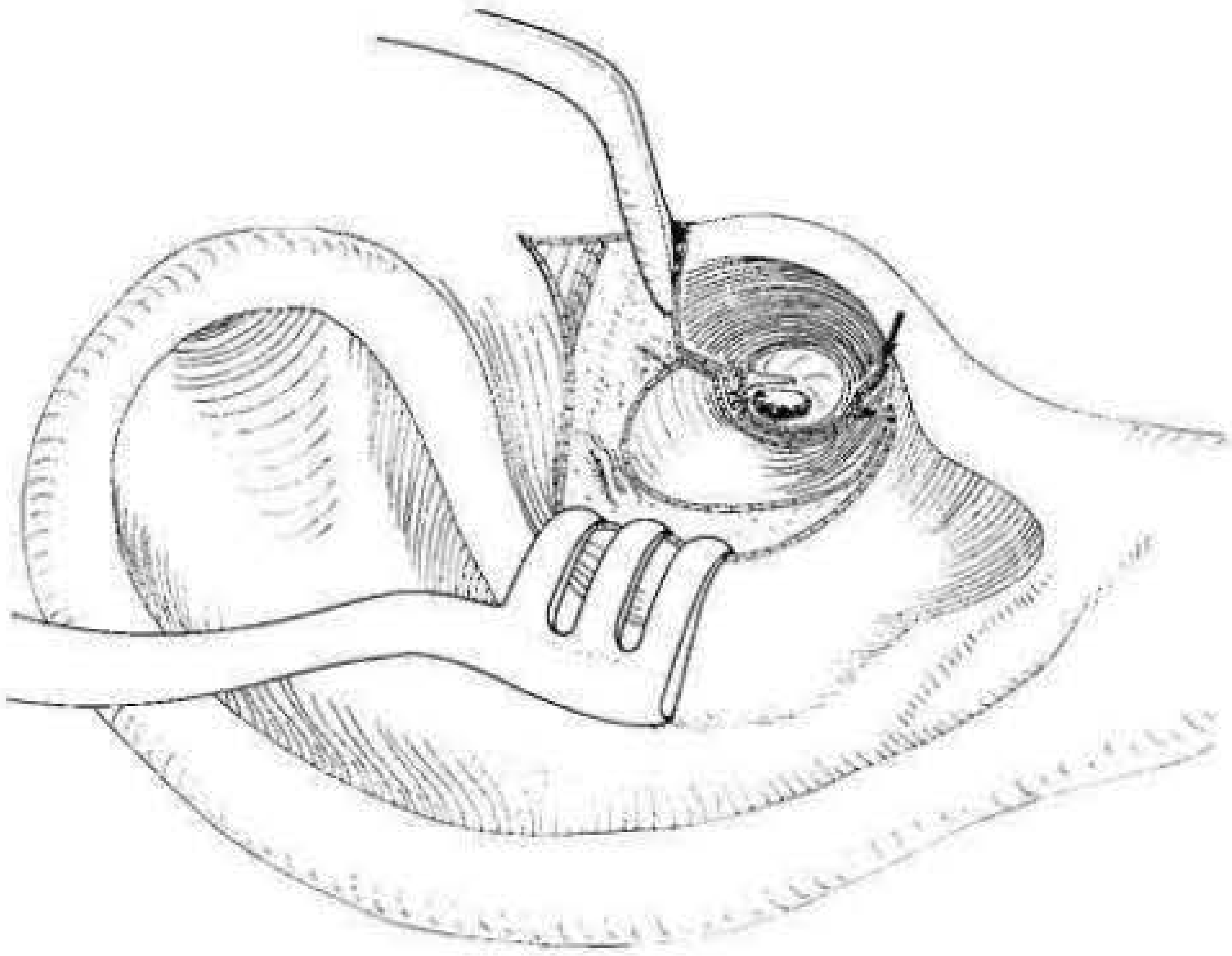


Fig. **534** The endaural incision in Wigand's technique. An intercartilaginous incision is made at the 12-o'clock position and a small vertical incision anterior to the helix. Between the 12-o'clock and 6-o'clock positions, a lateral circumferential incision at the level of Henle's spine and a medial circumferential incision 4 mm lateral to the annulus are performed. This incision is prolonged anterolaterally over the anterior canal wall in order to allow an easier retraction of the Stacke II canal skin flap (arrow)

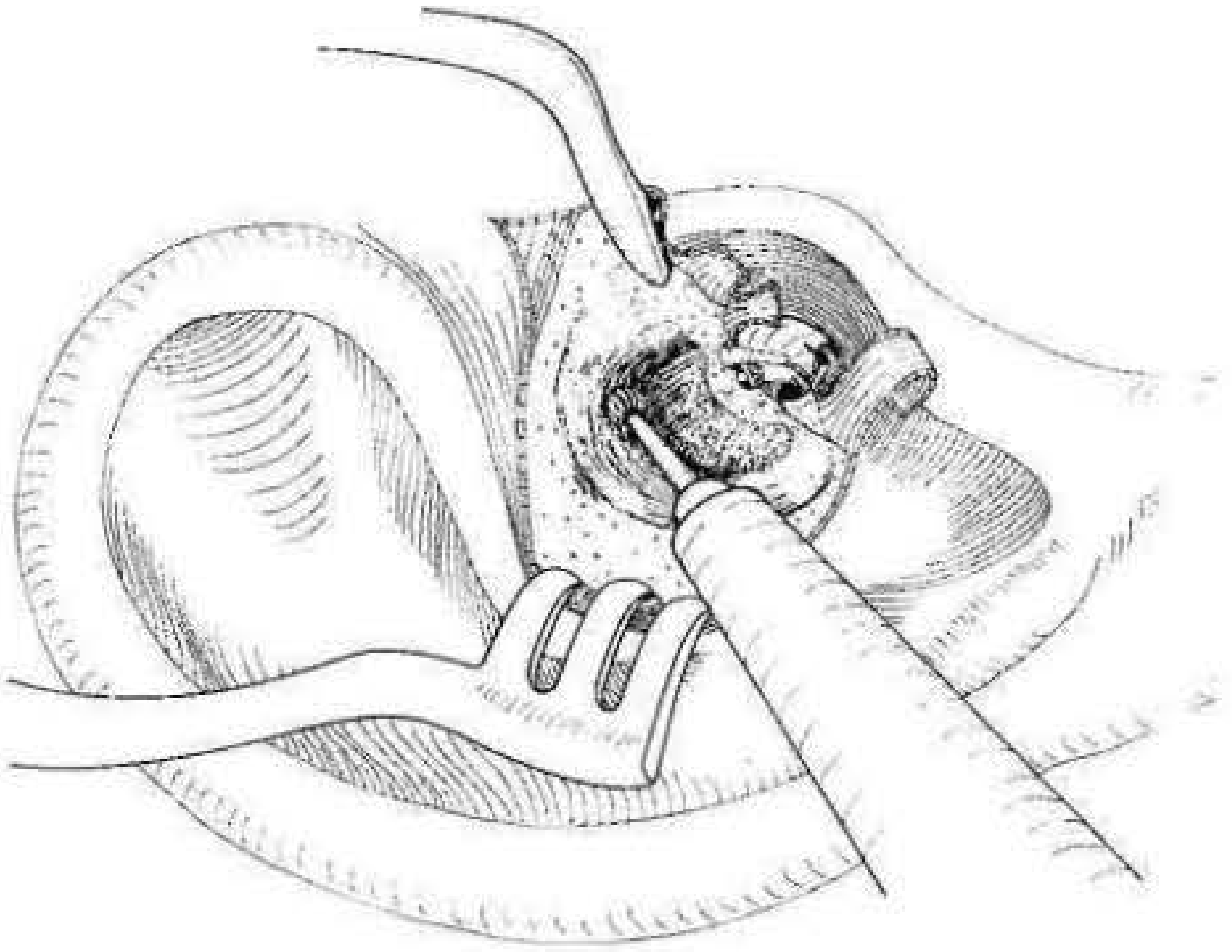


Fig. **535** A large Stacke II flap is elevated. Medially, superior and inferior tympanomeatal flaps are elevated (arrow). The ear canal is widened using a cutting burr

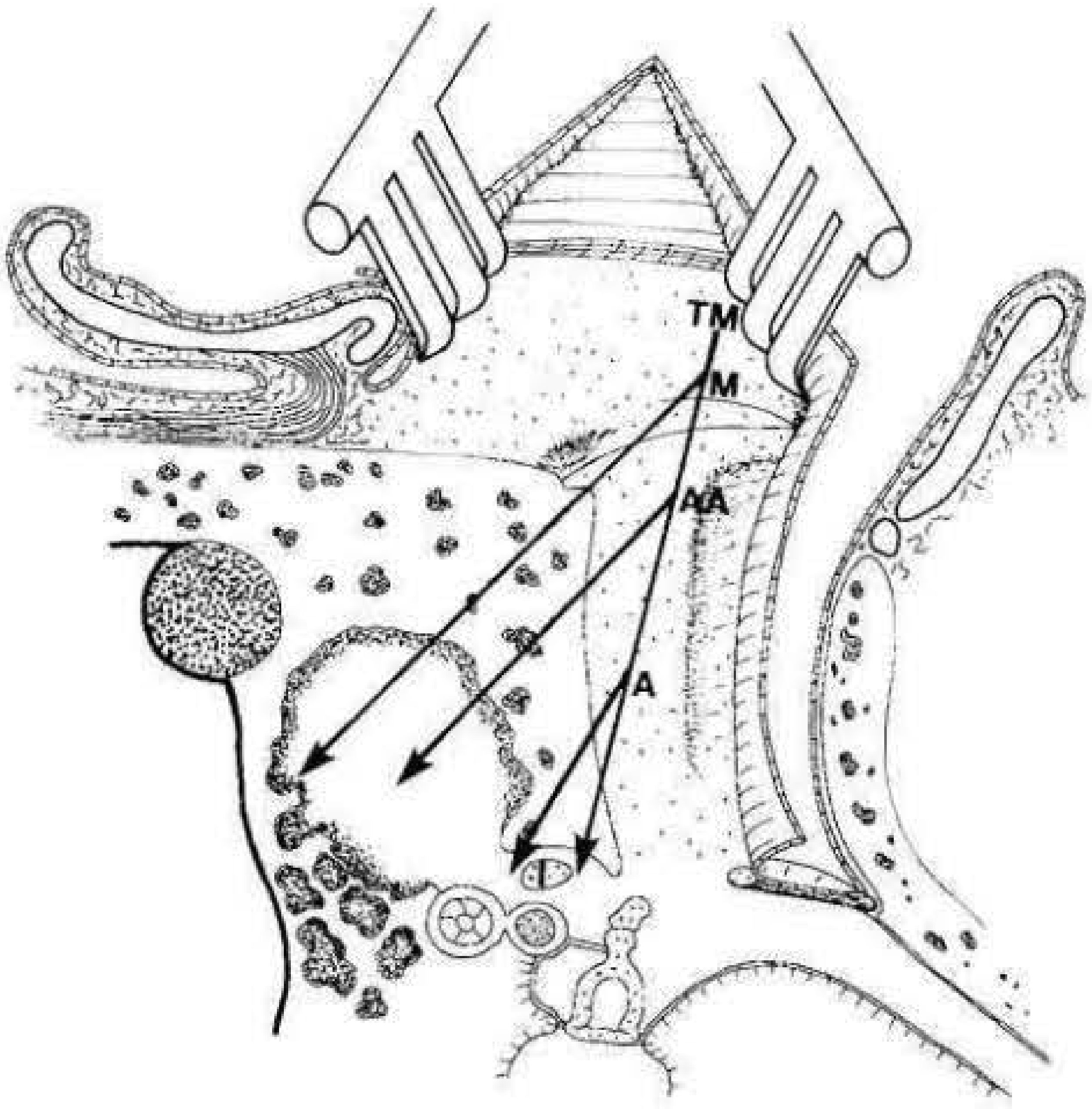


Fig. **536** Side view of the endaural approach, illustrating the transmeatal (TM) drilling route for atticotomy (A), inferior or superior to the incus body (I), for atticoantrotomy (AA) and mastoidectomy (M)

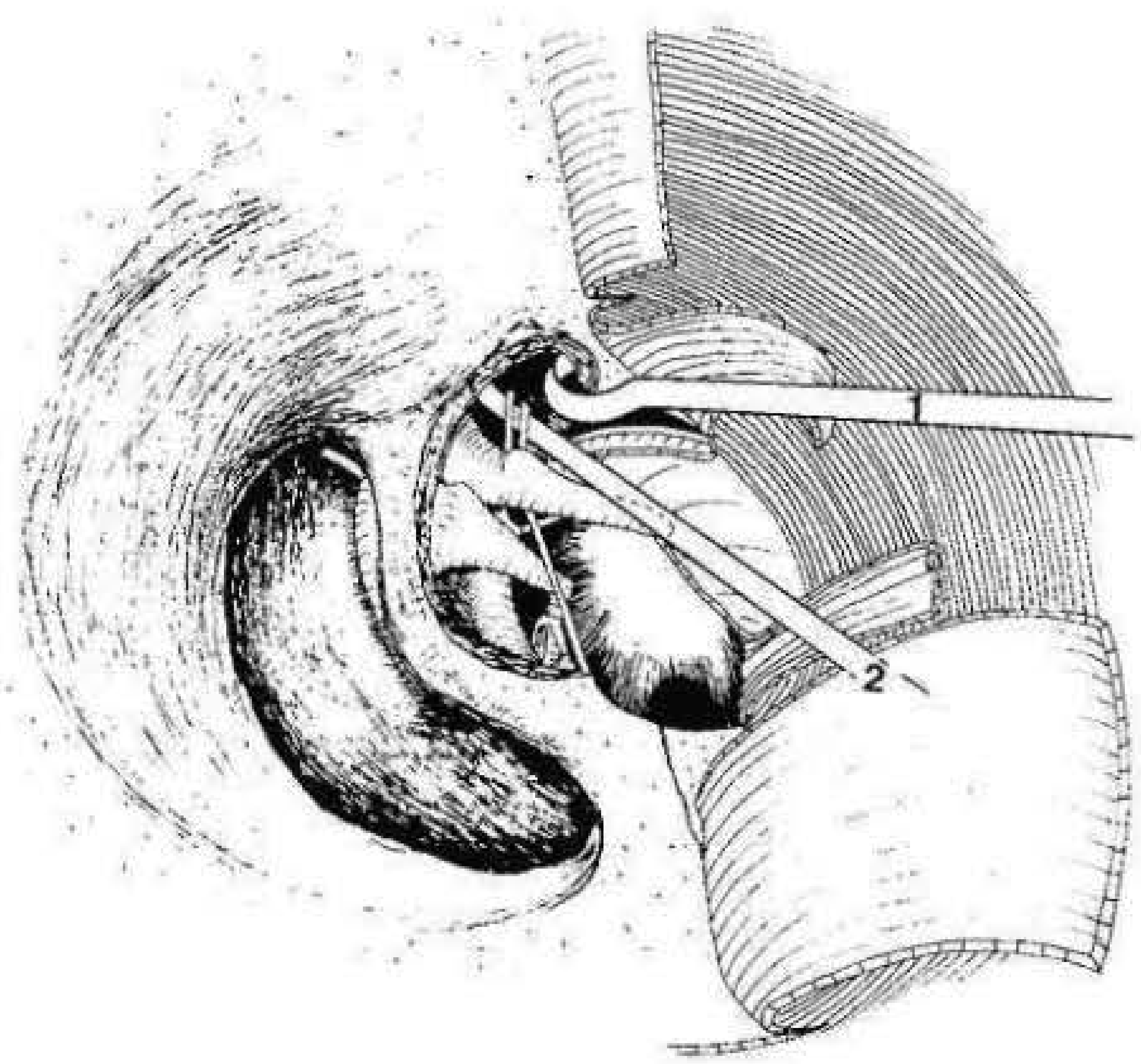


Fig. **537** **Tympanomeatoplasty with preservation of the bony bridge.** After extensive transmeatal enlargement of the ear canal, an antrotomy opening is performed. Medially, a small atticotomy is performed, exposing the anterior malleolar ligament, the neck of the malleus, and the long process of the incus, as well as the mesotympanum. Atticotomy drilling can be extended posteriorly. Under the anterior remnant of the bridge, the epitympanic sinus can be entered transmeatally (1) or transtympanically (2) under the anterior malleolar ligament and chorda tympani

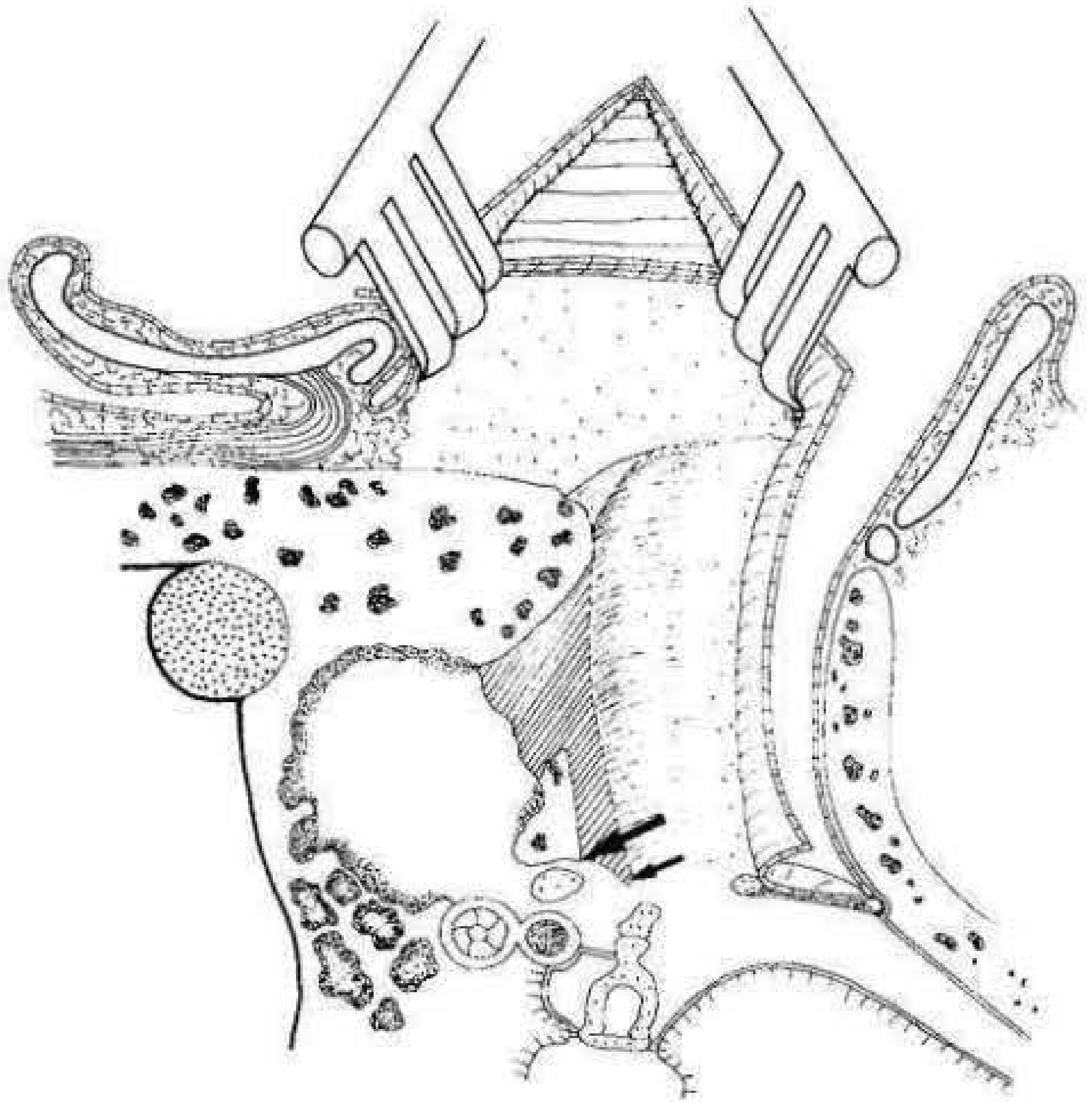


Fig. **538** **Side view of the tympanomeatoplasty with preservation of the bony bridge.** The ear canal is widened for about 2 mm, and an antrum control opening is performed (shaded area). Medially, the removal of the bony annulus (small arrow) creates a small atticotomy inferior to the malleus and incus. With further removal of the bony bridge, a larger atticotomy can be performed (large arrow)

lateral tympanic sinus and the pyramidal eminence (Fig. **537**). Any pathology from the tympanic cavity, for instance sinus cholesteatoma, is then removed, and the cholesteatoma membrane is carefully elevated, preserving the middle ear mucosa and the bony structures as far as possible intact.

If the pathology requires it, for instance if there is a deep sinus cholesteatoma, further drilling of the posterior bony annulus, around the chorda tympani, can be performed (Fig. **537**), providing exposure to all four tympanic sinuses. In attic cholesteatoma, further drilling allows transmeatal exposure of the epitympanic sinus and removal of the pathology both transtympanally, under the remaining bony bridge, as well as transmeatally, under the malleolar ligament and chorda tympani. If necessary, further drilling of the lateral attic wall can be performed in order to achieve better exposure of the anterior attic. The anterior bony plate (the cog) must be drilled away in order to open the epitympanic sinus and the protympanum (Fig. **537**).

The drilling continues posteriorly, and the lateral half of the ear canal is drilled away in order to widen the antrotomy opening (Fig. **539**). Further drilling is performed along the mastoid tegmen and tegmen antri, and especially on the posterior aspect of the preserved bony ear canal wall, in order to make it as thin as possible (Fig. **540**).

By tilting the patient in an anterior direction and further thinning the bony ear canal wall from both the mastoid and the meatal sides, a good view of the antrum and the attic as well as the facial recess region is achieved (Fig. **541**).

The bridge can be further lowered to about 1 mm (Fig. **533**) and further thinned by drilling its meatal and mastoid surfaces (Fig. **542**). The thinning of the bridge, especially along its medial edge, is important in order to avoid attachment of the cholesteatoma to the bridge.

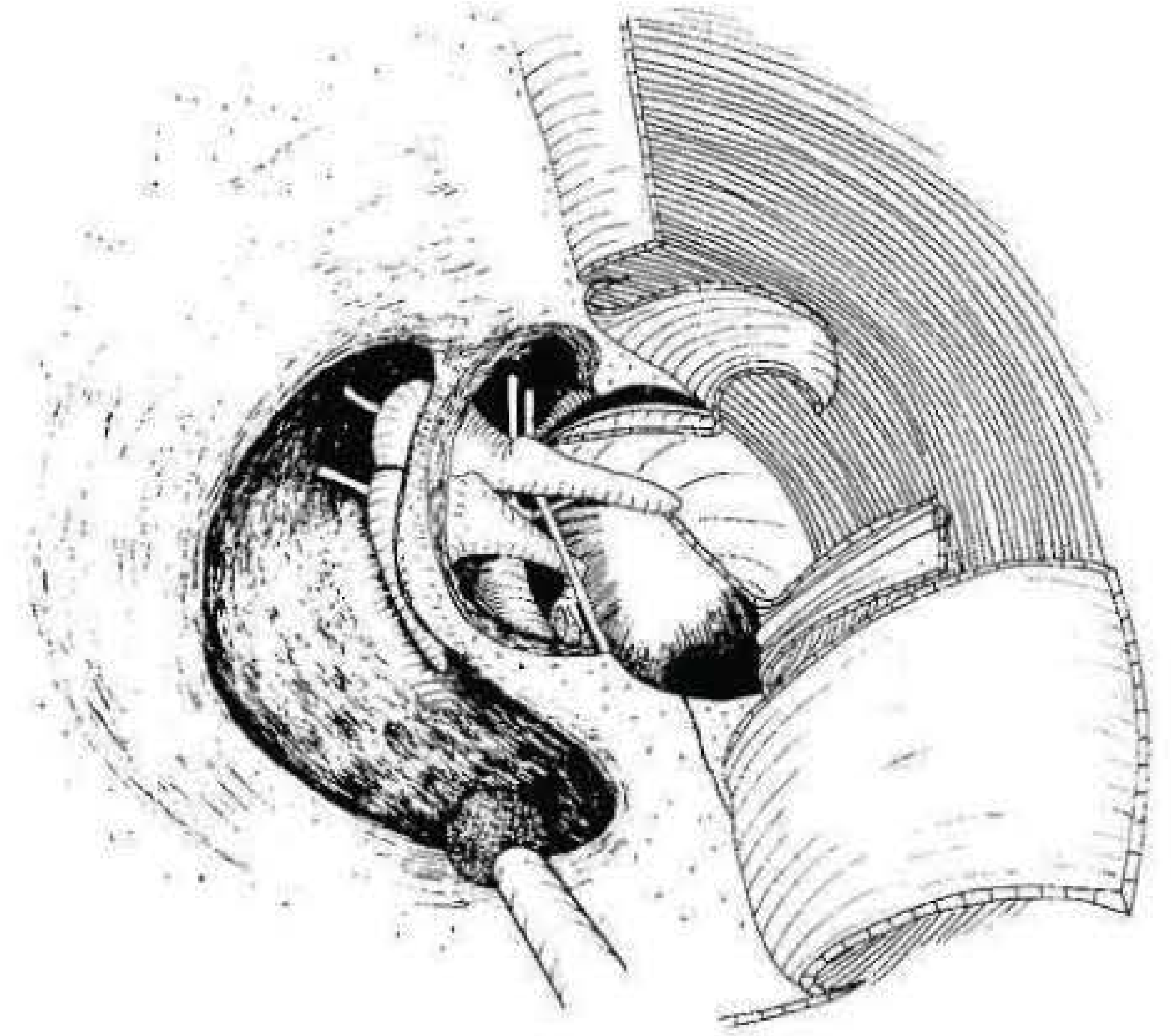


Fig. **539** The atticotomy opening is enlarged, and the bone from the mastoid tegmen and tegmen antri is drilled away. At the same time, the bony ear canal wall is also thinned on the mastoid side, and the antrotomy opening is enlarged

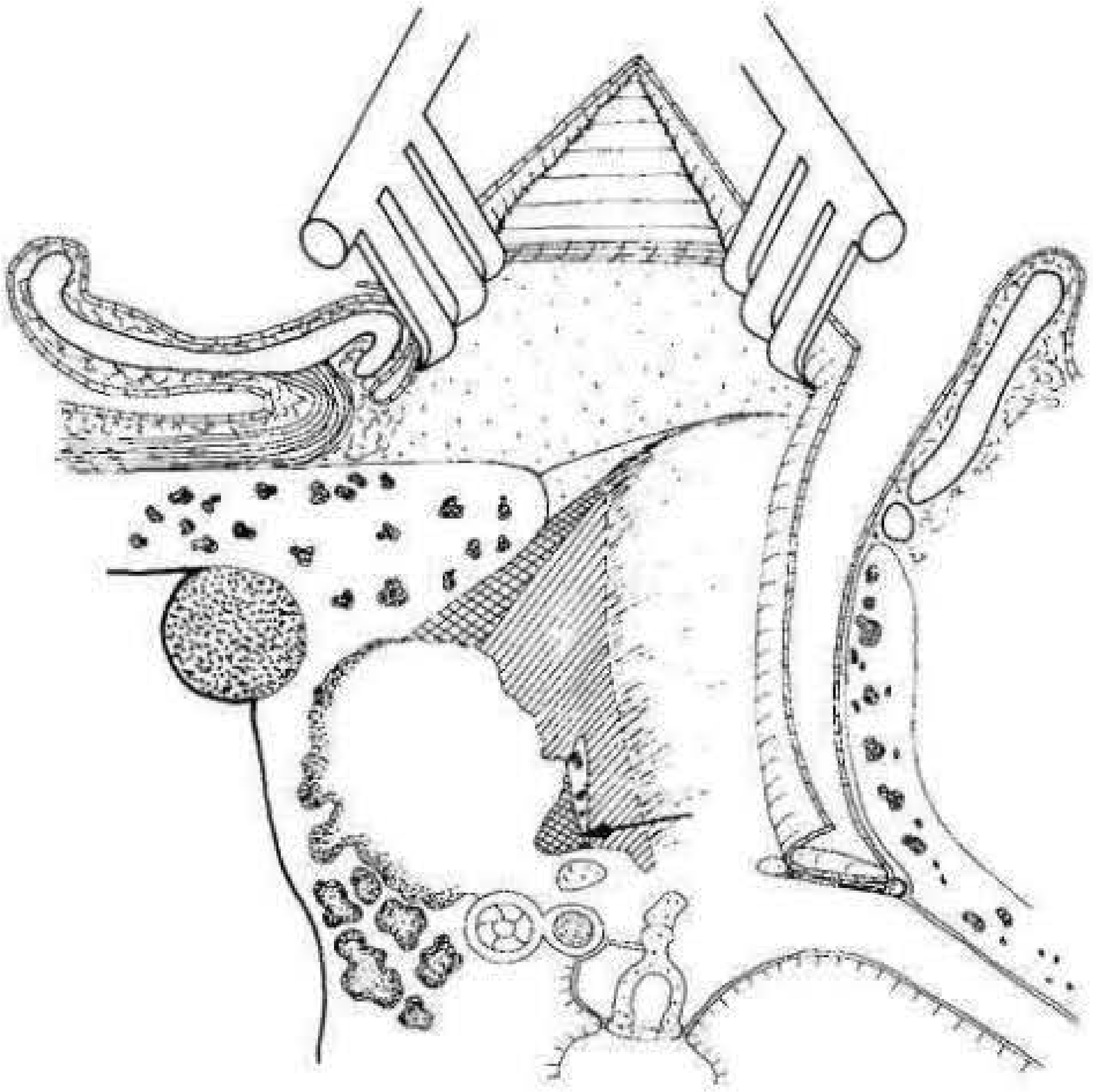


Fig. **540** Side view illustrating further enlargement of the antrotomy (shaded area) with thinning of the bony ear canal from the mastoid side (hatched area). The bone anterior to the suprameatal spine is removed (hatched area, arrow). The bony ear canal wall is thinned from both sides

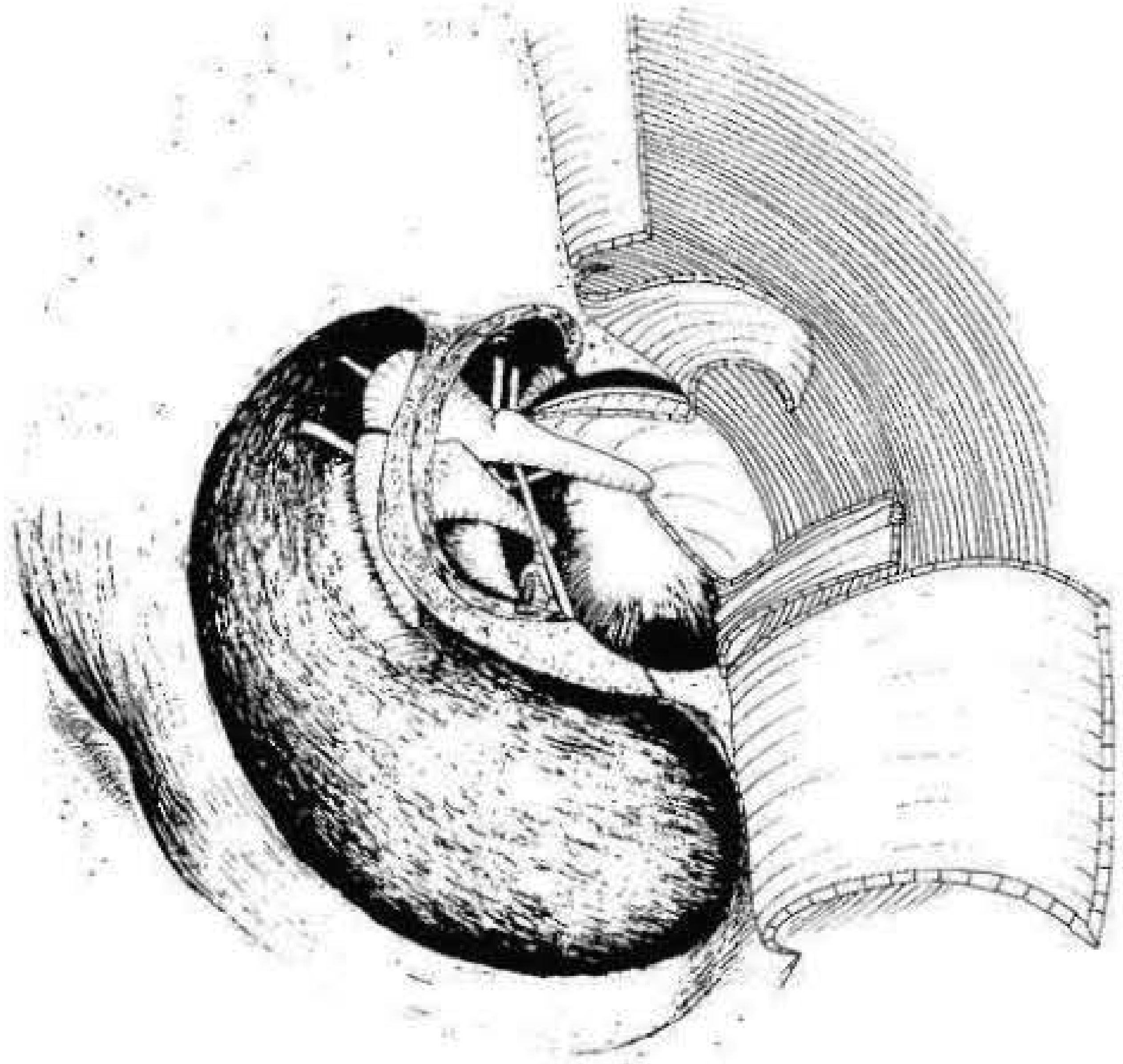


Fig. **541** Tympanomeatoplasty with further thinning of the bony ear canal wall from the mastoid side, allowing exposure of the attic and antrum. The drilling is continued toward the mastoid tip, and the antrum is enlarged

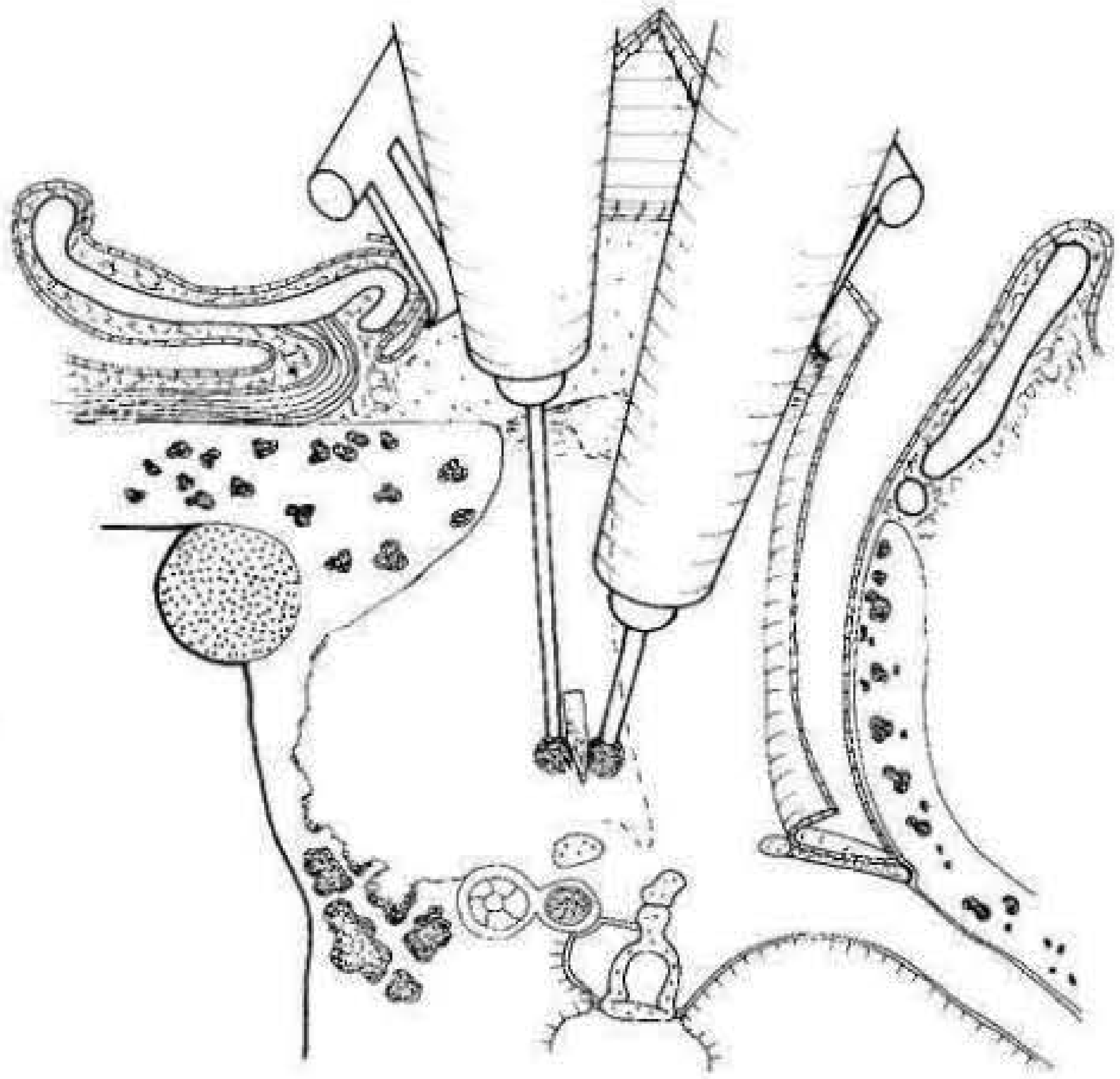


Fig. **542** Side view illustrating the thinning of the bony ear canal wall from the meatal and the mastoid sides

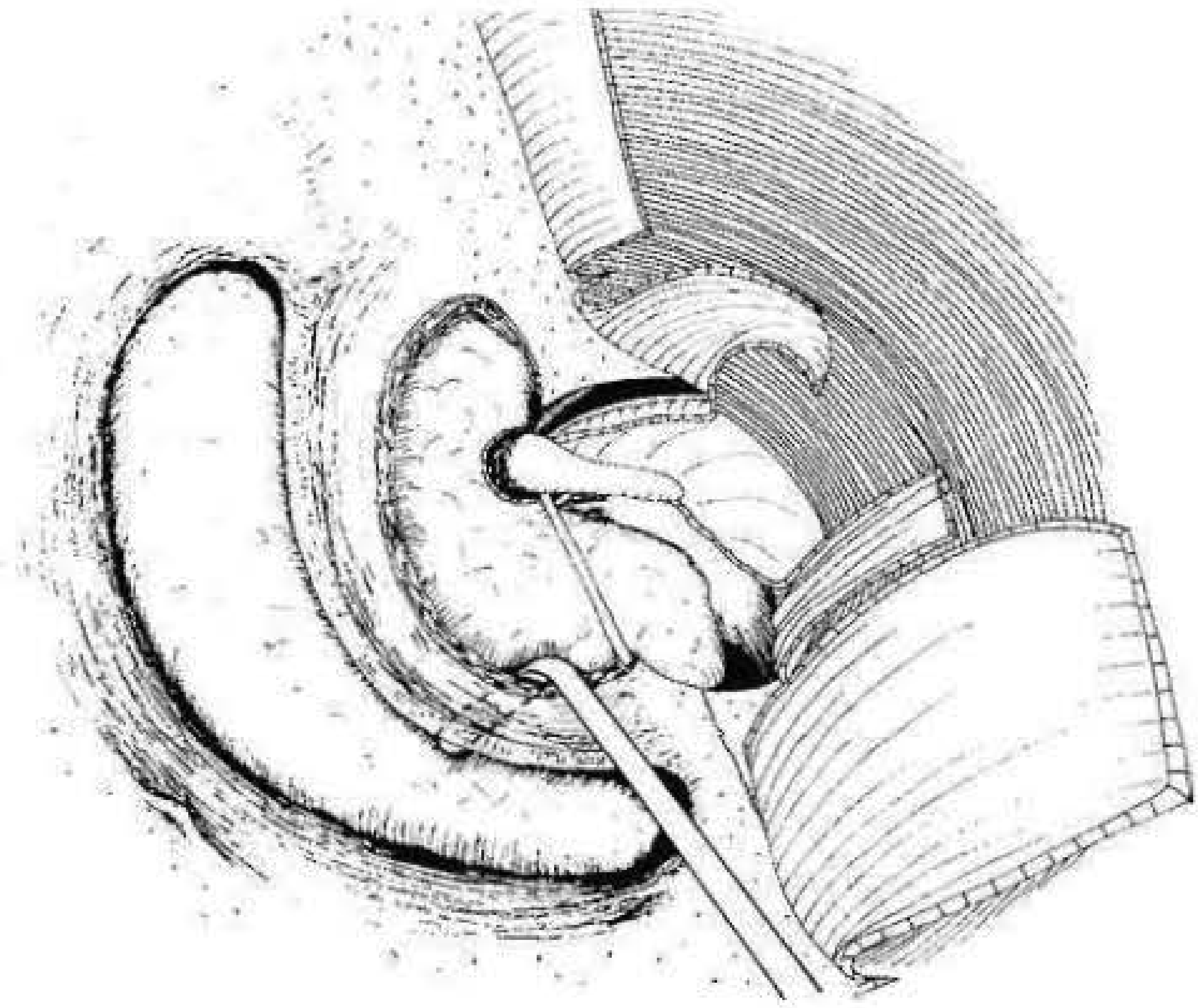


Fig. **543** Removal of a large attic cholesteatoma. extending into the tympanic cavity, by tympanomeatoplasty with preservation of the bony bridge. The antrotomy and atticotomy are performed, and the cholesteatoma is exposed

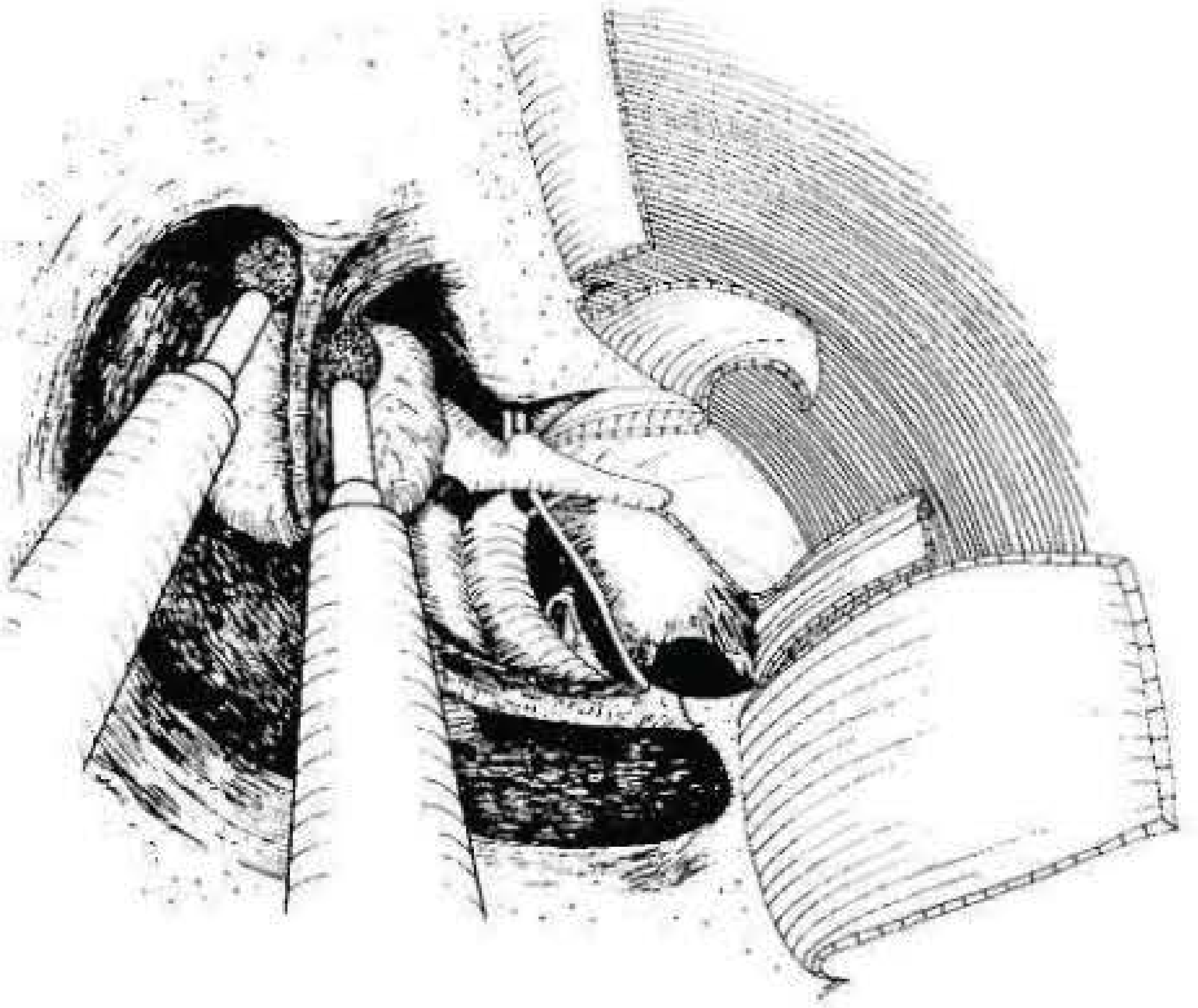


Fig. **544** The bony bridge is thinned from both sides, and the cholesteatoma is debulked and gradually elevated from the tympanic cavity and the antrum

Cholesteatoma Removal in Tympanomeatoplasty

The transmeatal and transcortical dissection of cholesteatoma is best illustrated by a case of a large attic cholesteatoma with extension into the tympanic cavity (Fig. **543**). Using enlargement of the ear canal and atticotomy and antrotomy, the cholesteatoma is exposed in the antrum, attic, and tympanic cavity. It is first elevated from the posterior attic (Fig. **543**) and the posterior tympanum. After debulking the cholesteatoma sac and elevating it from the antral walls (Fig. **544**), cleaning of the bony ear canal takes place from the meatal and mastoidal sides. With further thinning of the bony ear canal from the meatal side, the canal wall becomes further displaced superolaterally, allowing a good view of the attic region so that final elevation of the cholesteatoma membrane from the malleus head and the attic wall can take place (Fig. **544**). The removal of a large cholesteatoma results in a thin, posterolaterally displaced bridge, an open antrum, and a posterior attic that will later be covered and repneumatized (Fig. **542**).

Removal of sinus or tensa retraction cholesteatoma is facilitated by wide exposure of the posterior tympanum and posterior attic, as illustrated in Figures **543–545**.

Reconstruction of the Tympanomeatoplasty

The preserved bridge, even if it is superolaterally displaced and small, provides sufficient support for reconstruction of the ear canal. An ossiculoplasty or malleostapediopexy (Fig. **545**) is performed, and the drum perforation is closed with fascia as an underlay graft. The fascia will also cover the medial part of the reconstructed lateral attic wall and the ear canal (Fig. **546**). The lateral meatal defect, is small, it is covered with a layer of periosteum, harvested from the mastoid at the beginning of the operation, and is fixed with fibrin glue (Figs. **546, 547**). If the defect is large, it is covered by autogenous tragal or conchal cartilage, or homogenous septal cartilage (Figs. **546, 548**).

Because of the superolateral displacement of the bridge, the distance to the middle fossa dural plate is small. The defect in the lateral attic can either be covered with fascia alone (Fig. **548a**), or with cartilage plates placed over the thinned and laterally displaced bridge (Figs. **546, 548b**). Even if retraction occurs, it will remain shallow in the presence of an intact malleus and cleaning such a retraction is still possible.

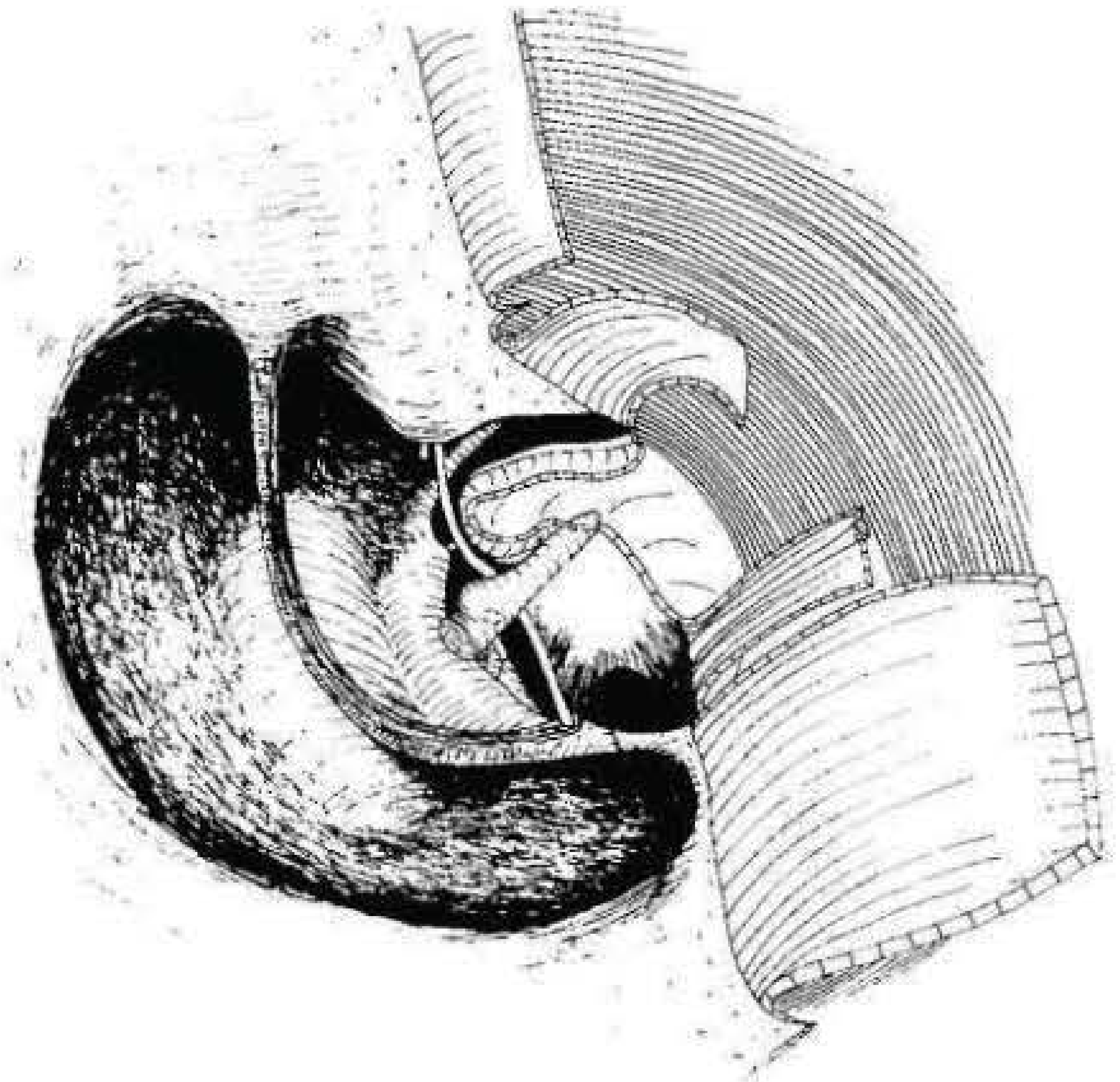


Fig. **545** Situation after removing the cholesteatoma: a large antrotomy and a small mastoidectomy, with preserved bony bridge. A malleostapediopexy is performed after mobilization of the malleus handle from the drum remnant

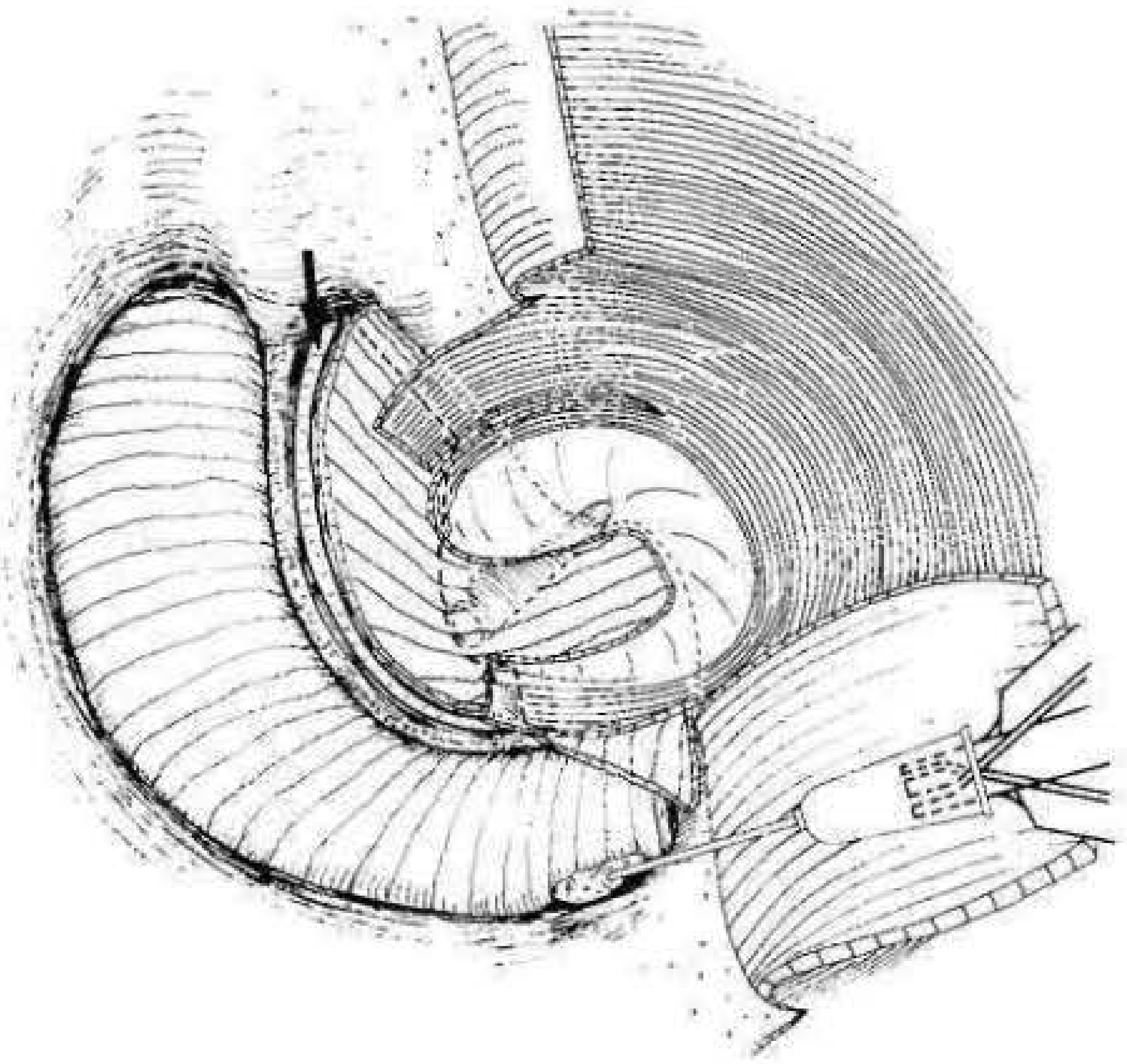


Fig. **546** **Reconstruction of the tympanomeatoplasty.** A cartilage plate is placed between the malleus handle and the bony bridge covering the attic (arrow). The drum perforation is covered with fascia as an underlay graft. Laterally, the antrotomy is covered with the periosteum, and fixed to the bone with fibrin glue

In cases with only a small bridge remaining, the attic region can be covered with fascia alone (Fig. **549a**). Covering the bridge and the malleus head with a piece of conchal or tragal cartilage placed between the malleus head and the displaced bridge, as well as between the bridge and the tegmen tympani, provides a firm reconstruction of the attic (Fig. **549b**).

Reconstruction of the ear canal defect in the antrum region is more difficult, because usually a larger defect has to be covered. As mentioned before, Wigand uses periosteum with small defects (Fig. **547**), but in larger defects a covering of cartilage, periosteum, and fascia has to be used (Fig. **550**). In cases with a small bridge, a large piece of cartilage is employed to cover the atticoantrotomy opening between the bridge and the cortical bone laterally. In addition, a cartilage plate covers the atticotomy medially (Fig. **551**). The cartilage may be covered with periosteum and fascia.

If retraction occurs, then the entire wall will gradually become retracted and the bony bridge becomes resorbed, resulting in an open atticoantrotomy cavity with relatively wide access, because the ear canal has been widened transmeatally.

There is a considerable difference between retraction seen after Wigand's method and retraction after the classic intact canal wall technique. In

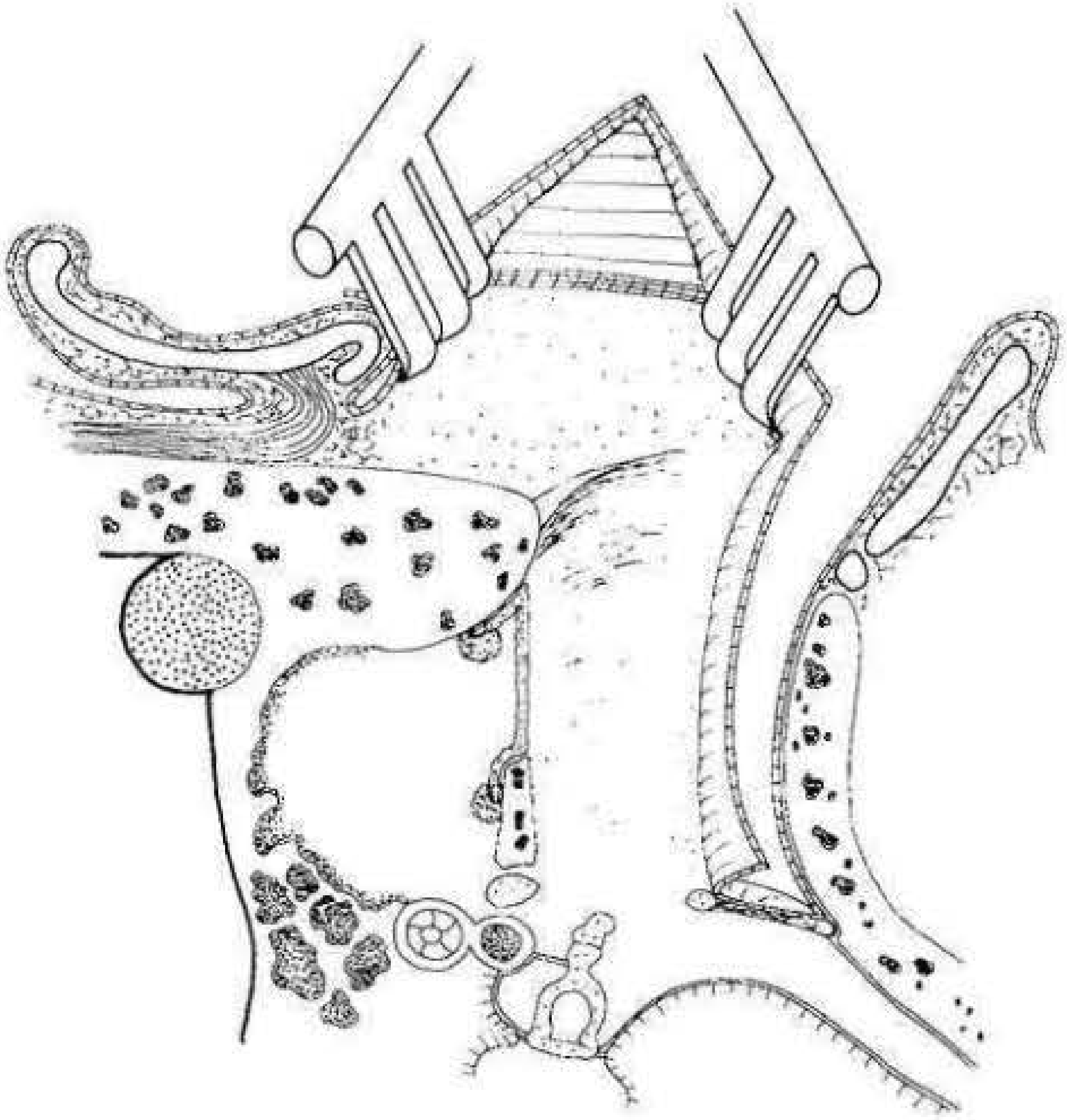


Fig. **547** **Side view of the tympanomeatoplasty.** The antrotomy is covered with periosteum, inverted into the antrum, and fixed with fibrin glue

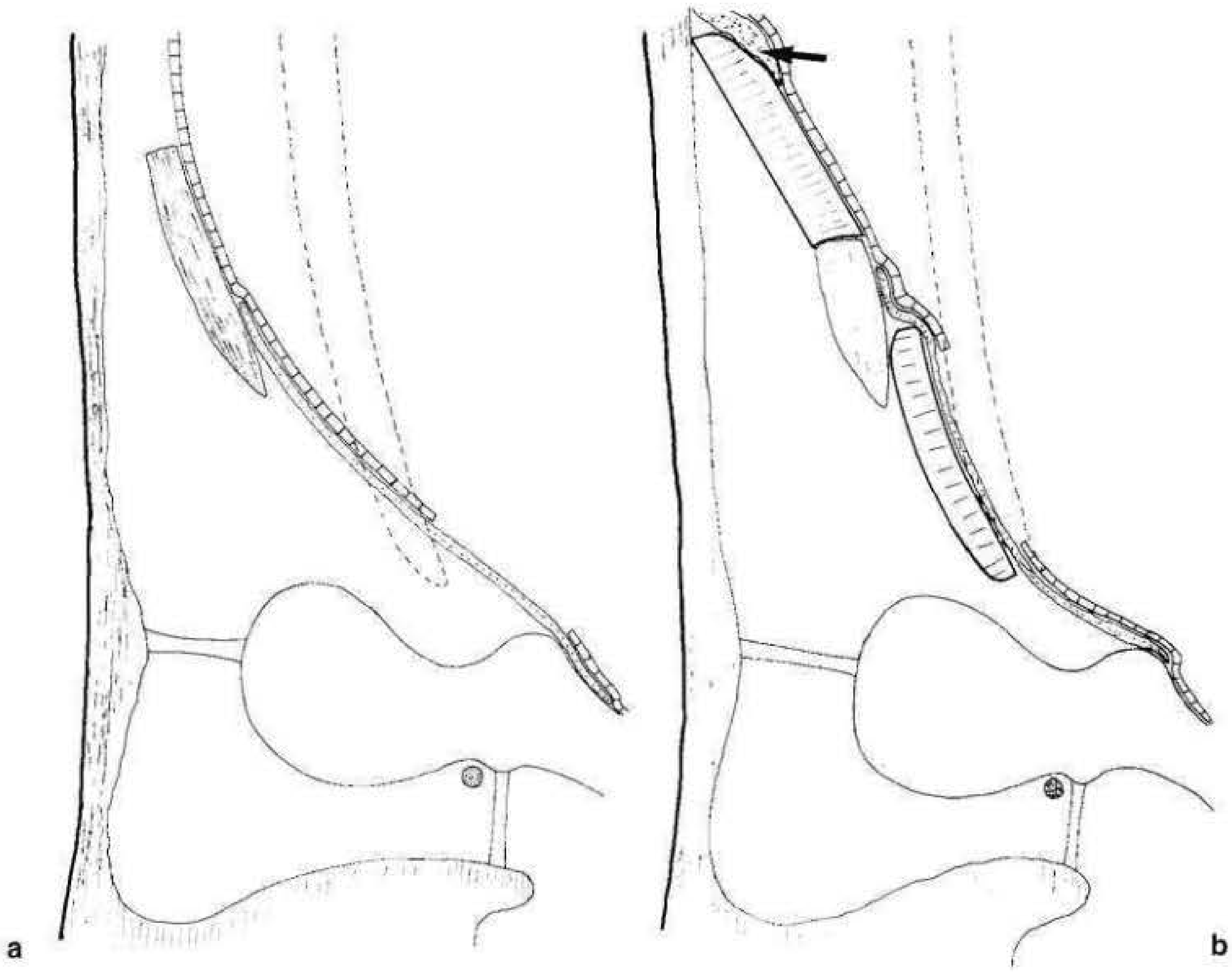


Fig. **548** **Reconstruction of the tympanomeatoplasty.** Posterior displacement of the bony ear canal wall after enlargement of the ear canal transmeatally, compared to the position of the ear canal wall after a classic intact canal wall mastoidectomy (dashed line). **a** The fascia covers the displaced bony ear canal wall. **b** The lateral part of the bony ear canal wall is reconstructed with a piece of cartilage placed on the remaining bone. The medial part of the ear canal wall is reconstructed with a cartilage plate placed between the malleus head and the preserved bridge. Fascia covers most of the reconstructed ear canal wall, and laterally the periosteum (arrow)

Wigand's method, retractions usually have wide necks, and may be selfcleaning, whereas in the classic intact canal wall technique, they more often have small necks and are therefore more dangerous.

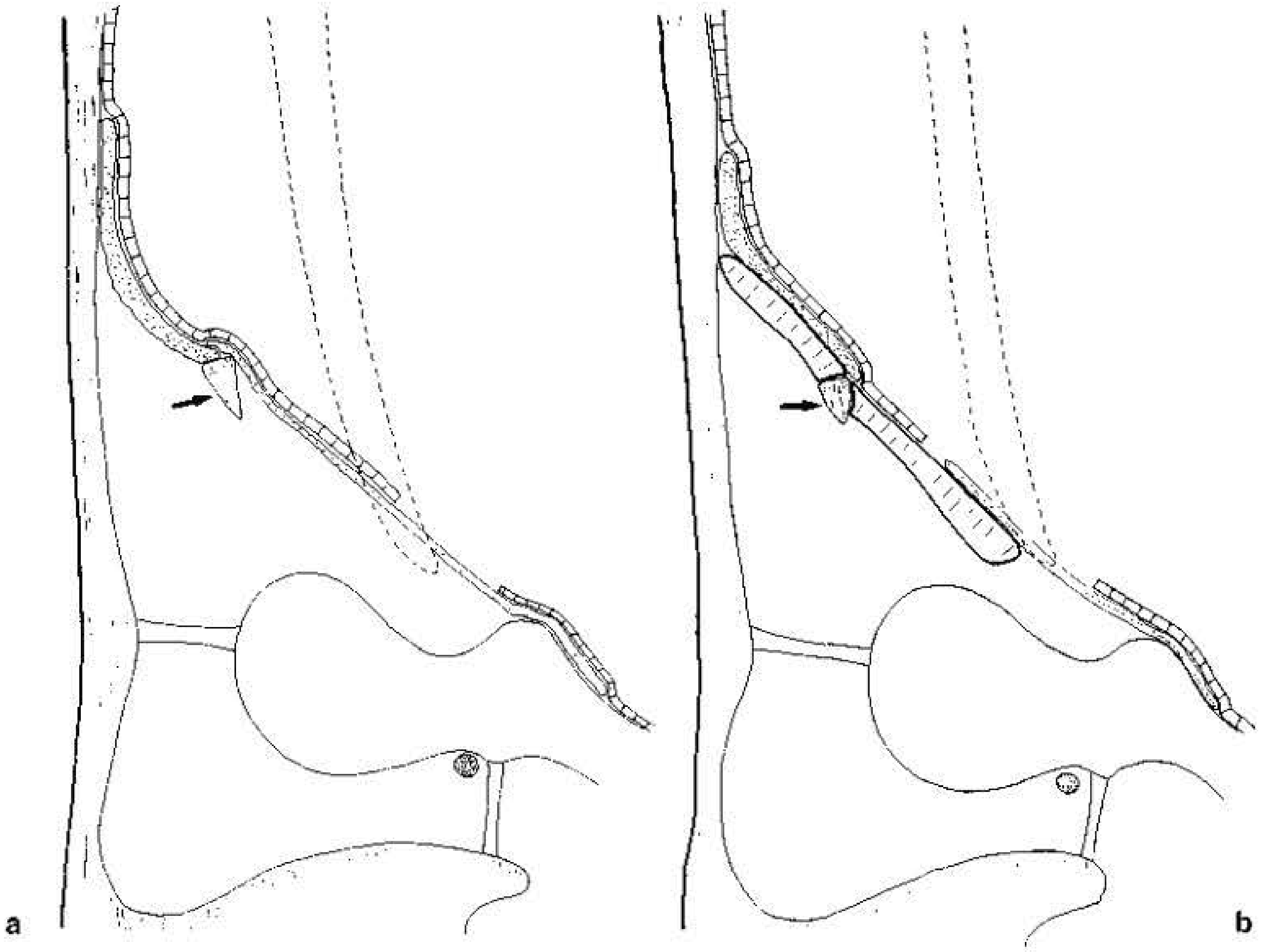


Fig. **549** **Reconstruction when only a small posterosuperior displaced bridge is preserved. a** A fascia extends from the malleus handle to the bridge (arrow). Periosteum is placed between the bridge and the mastoid tegmen. **b** A cartilage plate covers the attic region, extending from the head of the malleus to the bridge (arrow). Another cartilage plate covers the region lateral to the bridge. Medially, the cartilage is further covered with fascia, and laterally with periosteum

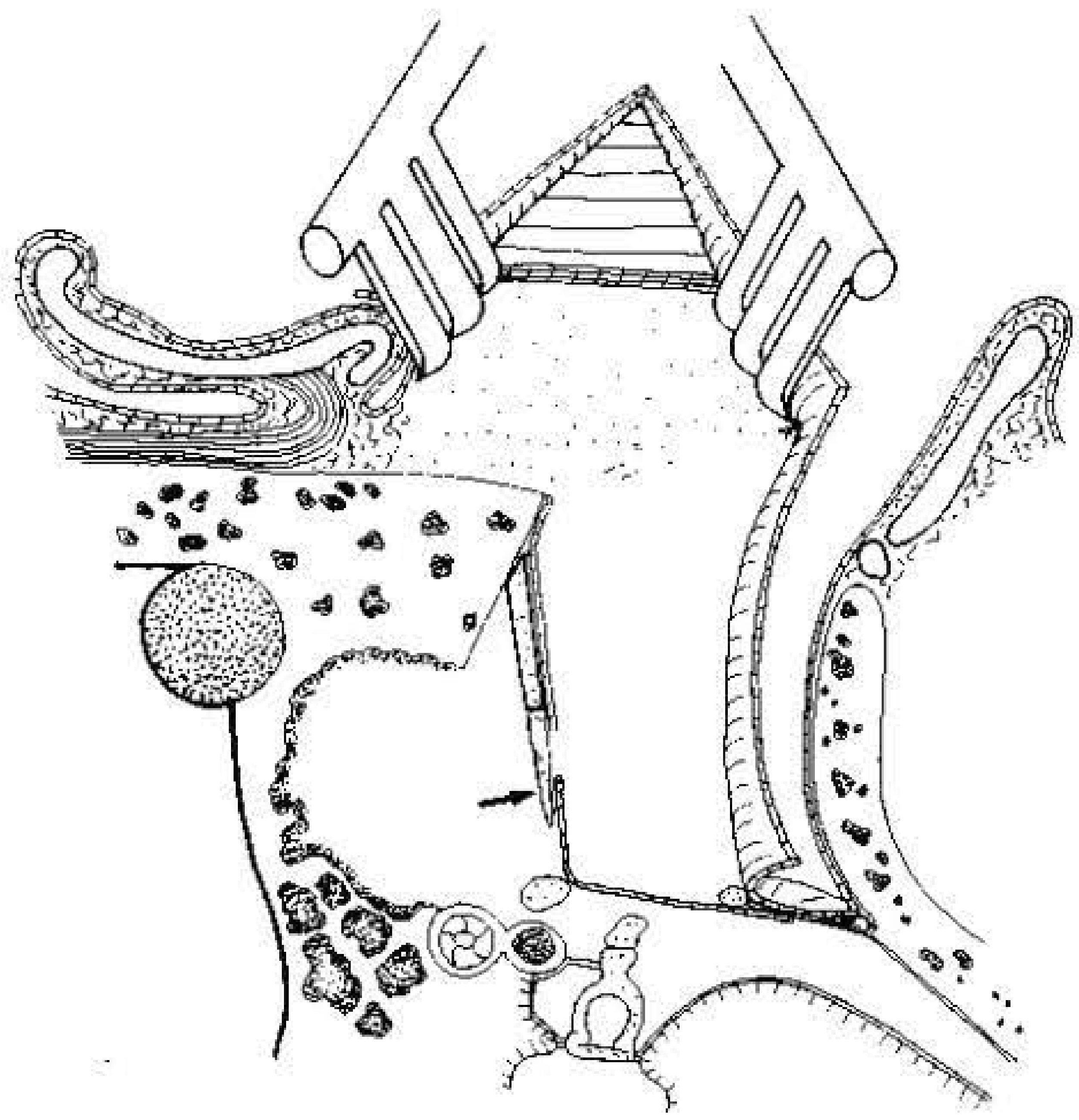


Fig. **550** **Side view of the reconstruction of the tympanomeatoplasty** at the level of the antrum. A small antrotomy opening (arrow) is covered with cartilage and periosteum

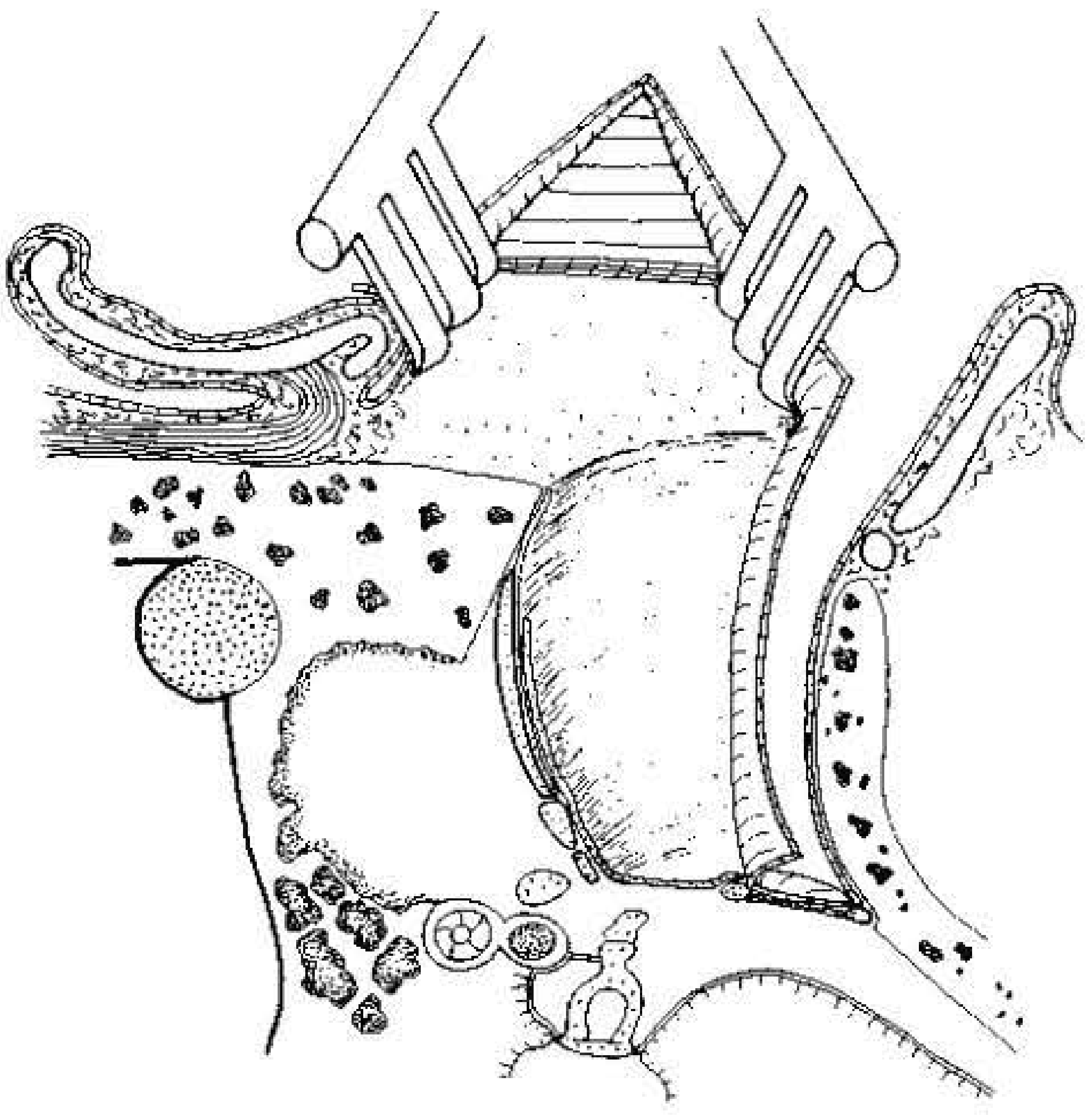


Fig. **551** A large antrotomy opening is covered with a large cartilage plate, placed on the bony bridge. The cartilage is also covered with periosteum laterally and fascia medially

10 Transmeatal Anterior Atticotympanotomy and Transcortical Mastoidectomy (Farrior)

Definitions

Farrior (1968, 1969, 1973), introduced this type of mastoidectomy for various types of cholesteatomas, the idea being to enlarge the bony ear canal widely, even as far as the middle fossa dural plate (Fig. **552**), perform a transcanal anterior atticotympanotomy, and safely clean the anterior attic. By further enlarging the posterior ear canal and removing the posterior bony annulus, the posterior tympanum and the tympanic sinuses are exposed. By performing a cortical mastoidectomy behind the enlarged ear canal, the remaining bony ear canal wall dividing the posterior mastoidectomy and the anterior tympanoplasty is displaced posteriorly (Fig. **552**). In the anterior transcanal atticotympanotomy the posterior canal wall is thinned at its anterior limit to expose the tympanic sinuses and to permit complete removal of the middle ear disease posterior to the stapes and the round window. This complete dissection creates a widely opened middle ear cavity, similar to that in a modified radical mastoidectomy, but still preserving the displaced bony ear canal wall and thus creating a closed mastoid cavity. Farrior's technique is based on repneumatization of the mastoid and the attic, but some modifications of the technique (Olaizola 1985, 1988, Bonding and Hinrichsen 1989) describe closure of the connection to the posterior mastoidectomy and cavity obliteration.

The Farrior Technique

Farrior (1968) uses his own technique, with a retroauricular approach (Vol. 1, Figs. **93–95**) and near complete removal of the ear canal skin.

After elevation of the subcutaneous tissue and periosteum from the mastoid plane, a lateral circumferential incision of the ear canal skin is performed at the level of Henle's spine. It starts at the 12-o'clock position, continues inferiorly to the 6-o'clock position and further anteriorly to the

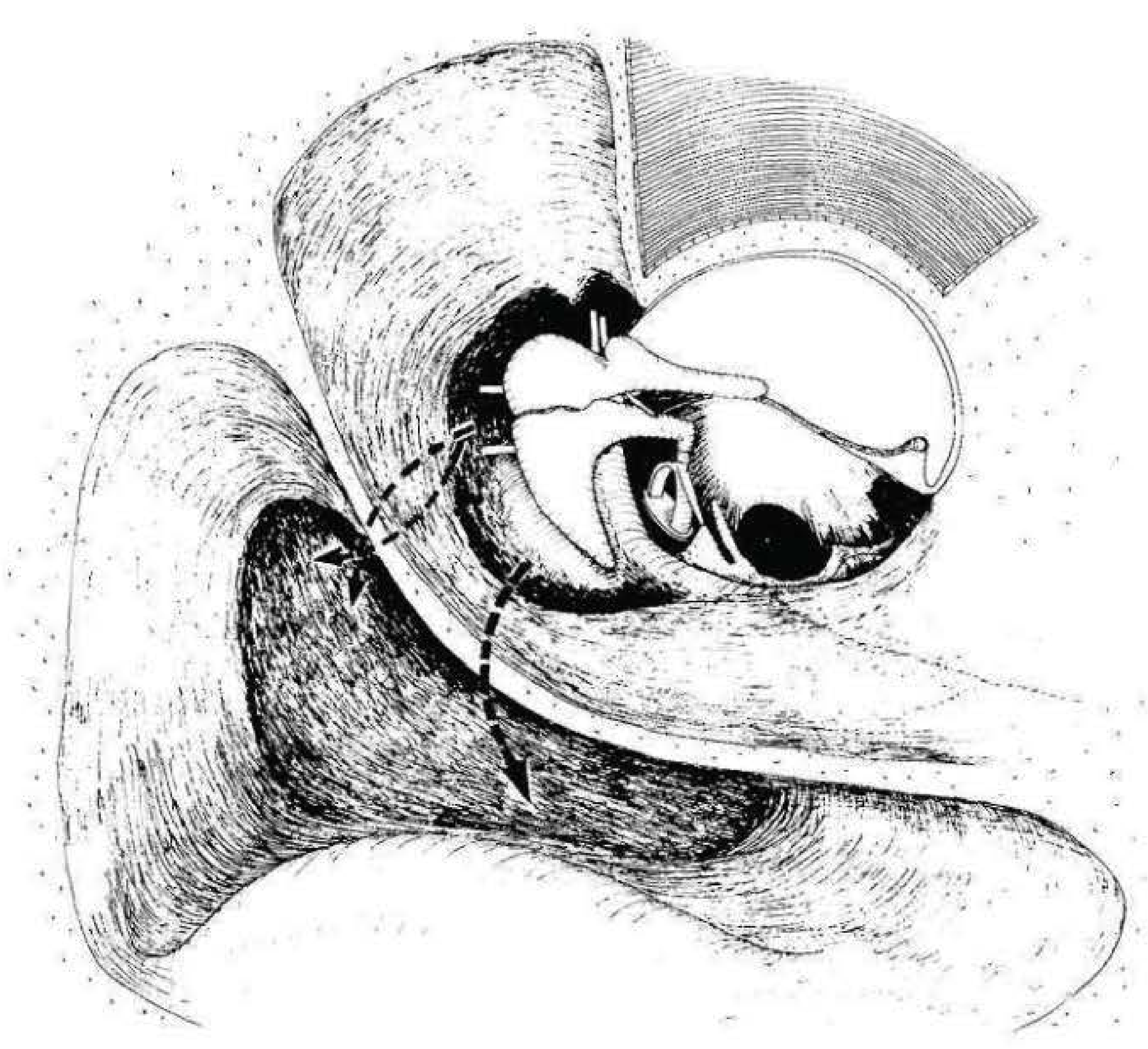


Fig. **552 Transcanal anterior atticotympanotomy and cortical mastoidectomy (Farrior).** A Farrior modification with the retroauricular approach is performed with removai of the ear canal skin, except between the 12-o'clock and 3-o'clock positions. The epithelium from the anterior part of the drum, in a situation of posterior perforation, is also removed. An anterior atticotympanotomy is performed by enlarging the ear canal up to the mastoid tegmen, leaving an intact but displaced bony ear canal between the posterior mastoidectomy and the anterior atticotomy, and exposing the entire medial wall of the attic with the lateral semicircular canal and the horizontal part of the facial nerve. The posterior bony ear canal is also widened, especially the bony annulus, exposing the genu of the facial nerve, the pyramidal eminence, the styloid eminence, and the tympanic sinuses. The drilling can be further extended to the hypotympanum. The idea is to ventilate the mastoid cavity (arrows)

3-o'clock position, leaving only the anterosuperior meatal skin intact (Fig. **553**). The meatal skin is removed, a small posterior transcortical mastoidectomy is performed, and extensive widening of the bony ear canal takes place (Fig. **554**). After otosclerosis drilling, the condition of the ossicular chain is investigated, and further removal of the bony annulus takes place. An atticotomy is performed, removing the bony annulus superiorly and posteriorly, and most of the lateral attic is thus exposed, as is the posterior tympanum. The bony ear canal is further enlarged towards the mastoid tegmen (Fig. **555**). Gradually, the entire lateral attic wall is removed, completely exposing the attic. The incus is removed, and good exposure is achieved of the medial attic, the lateral semicircular canal, and the horizontal part of the facial nerve (Fig. **556**). Anteriorly, the bony plate (the "cog") is removed, and a connection from the anterior attic to the epitympanic sinus and Eustachian tube is established in order to make repneumatization of the mastoid cavity possible.

If the pathology requires furter exposure of the posterior tympanum, e. g., in sinus cholesteatoma or tensa retraction cholesteatoma with involvement of the tympanic sinuses, further drilling of the posterior bony ear canal wall is performed, exposing the entire horizontal part of the Fallopian canal, the

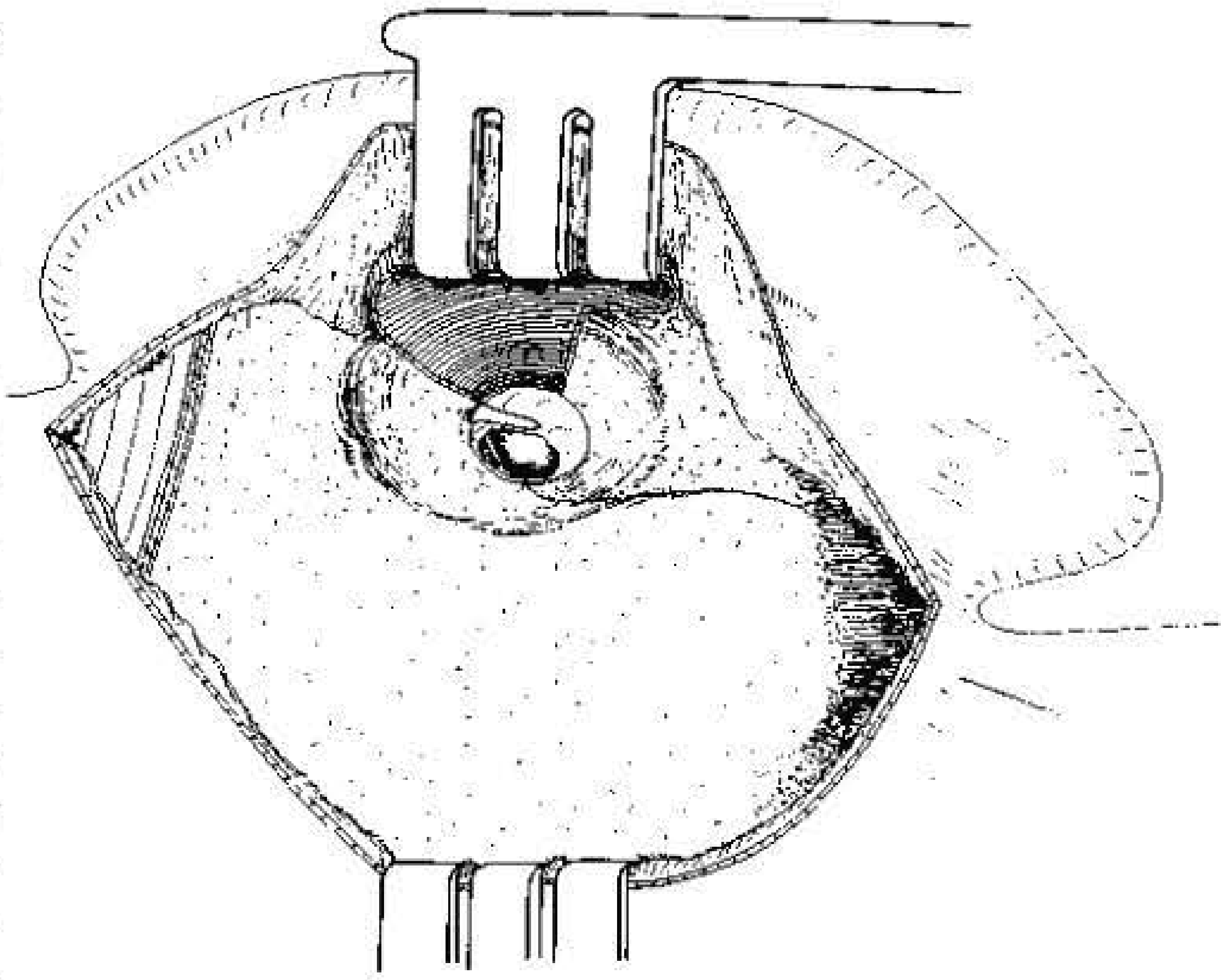


Fig. **553** The Farrior modification of the retroauricular approach, with exposure of the mastoid plane and the lower border of the temporalis muscle, as well as the terminal line, in a situation of sinus cholesteatoma and posterosuperior perforation. A circumferential ear canal incision between the 12-o'clock and 3-o'clock positions at the level of Henle's spine, and two radial incisions at the 12-o'clock and 3-o'clock positions are performed. These two incisions are connected with a circumferential incision close to the annulus

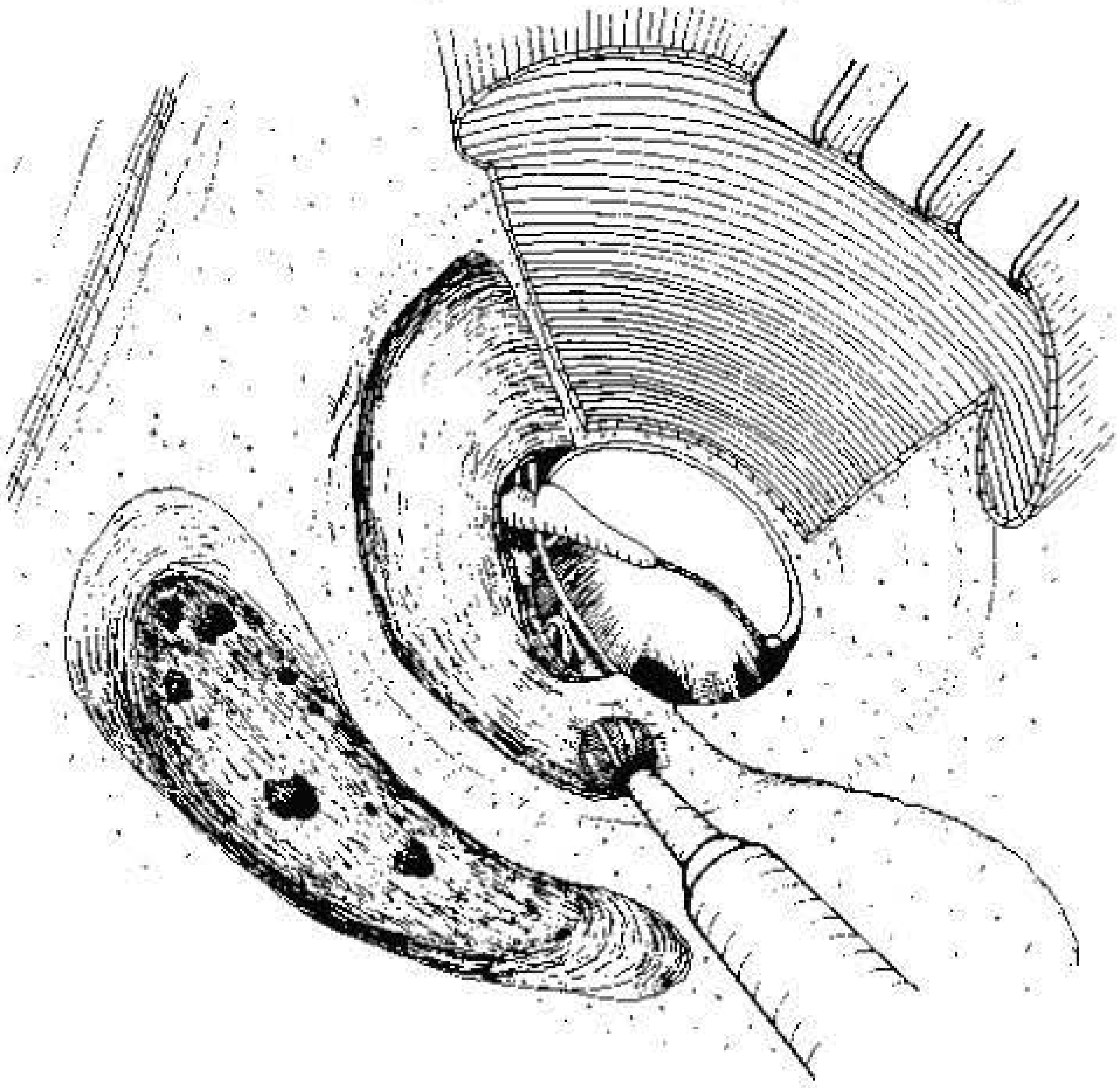


Fig. **554** The epithelium from the drum remnant and the canal skin is removed all the way around, exposing the superior, posterior, and inferior aspects of the bony ear canal. A small cortical mastoidectomy is performed far posteriorly, and the ear canal is widened from the 1-o'clock to the 9-o'clock positions. Osteosclerosis drilling is performed to obtain information about the ossicular chain

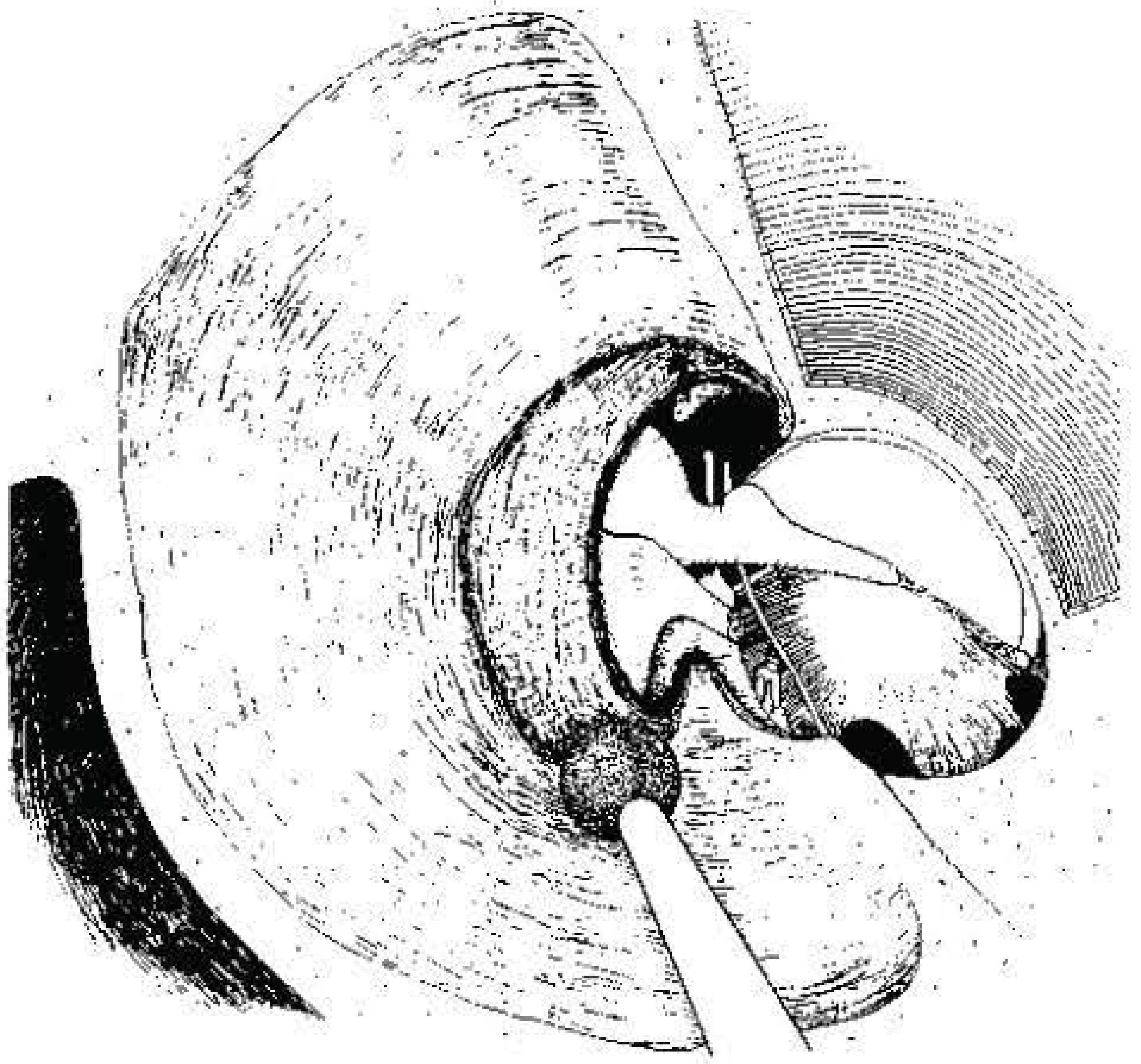


Fig. **555** With further enlargement of the ear canal and removal of the superior and posterior bony annulus, an atticotomy is performed, and part of the lateral attic is exposed. Posteriorly, with continuous drilling of the bony annulus, the facial nerve and the pyramidal eminence are exposed. The anterior bony plate (the cog) is visible (arrow)

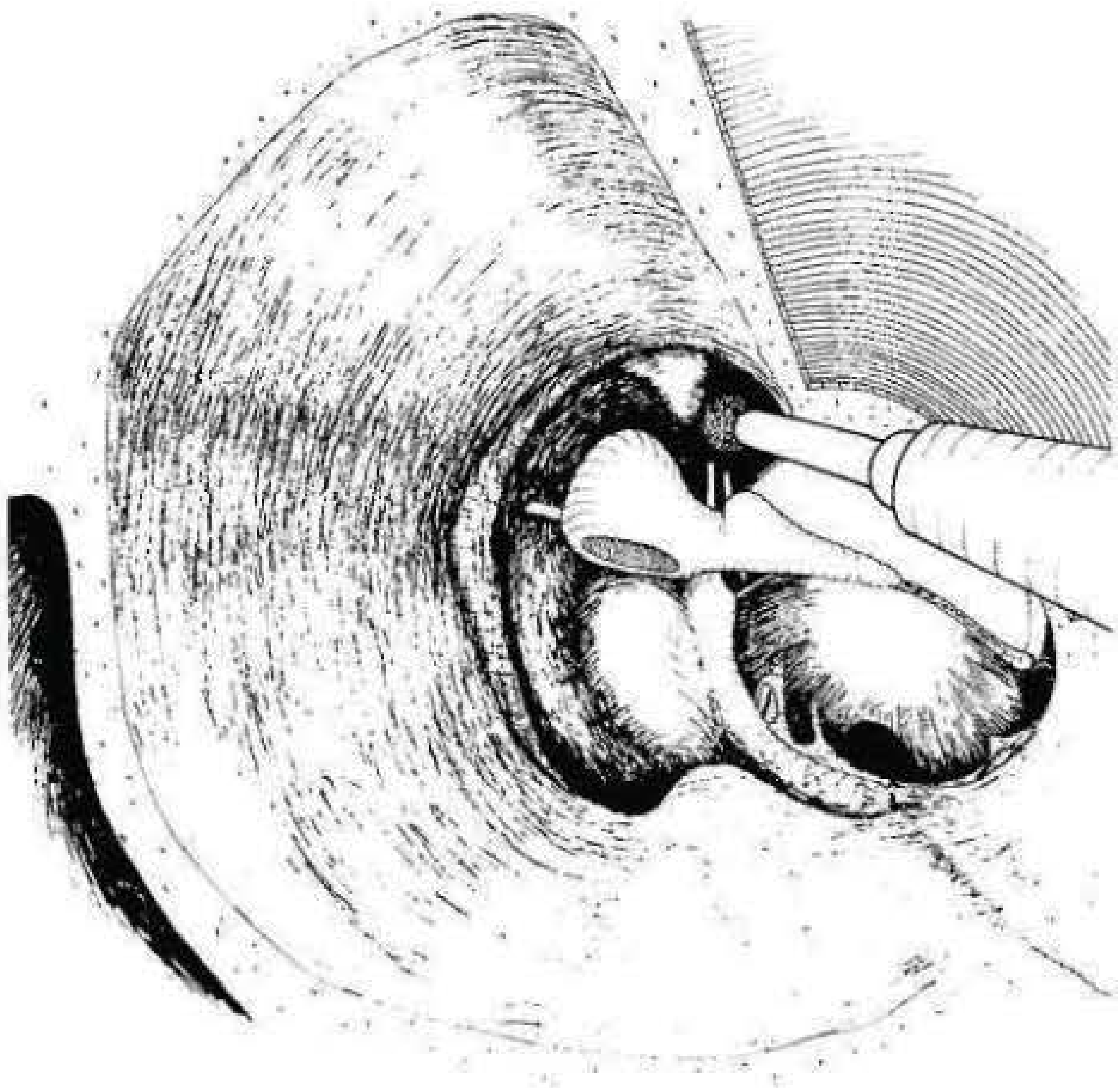


Fig. **556** The anterior bony plate is removed and the anterior attic is further exposed, allowing a good connection to the epitympanic sinus and Eustachian tube. The lateral attic wall is almost completely removed up to the tegmen tympani and antri. After removal of the incus, the posterior and the medial attic become visible, and removal of the cholesteatoma can be carried out

genu, and part of the vertical canal, as far as the chorda tympani, which can occasionally be preserved (Fig. **556**). Usually, the chorda tympani has to be sacrified, and the posterior bony ear canal is further removed, exposing more of the Fallopian canal and the styloid eminence. A good view is provided of the tympanic sinuses, and the cholesteatoma can be safely removed. If it is required, there is a good opportunity with this technique, to continue down into the hypotympanum in order to remove cholesteatoma.

To expose the entire attic, the overhangs of the mastoid tegmen and tegmen tympani are smoothened. After resection of the malleus head, as Farrior recommends, and after removal of all pathology, the transmeatal anterior atticotympanotomy is complete (Fig. **557**). One must now complete the transcortical posterior mastoidectomy in order to remove any residual disease in the antrum and the mastoid process (Fig. **558**).

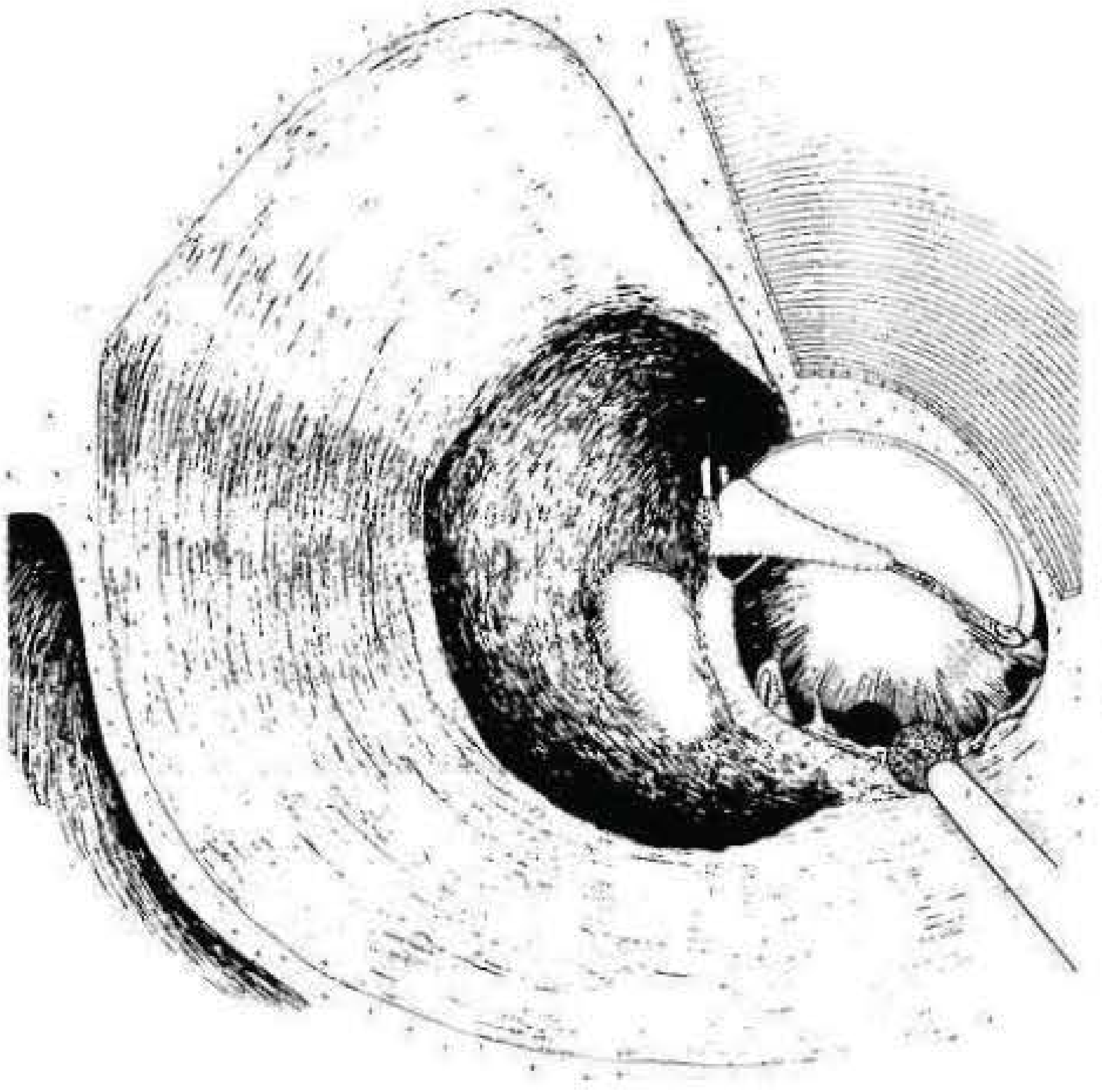


Fig. **557** The head of the malleus is resected, and the entire medial wall of the attic is cleaned. The bony overhangs of the lateral attic bone are removed, and the attic is enlarged as far as the tegmen tympani. The ear canal is further enlarged, and its bony wall is posteriorly displaced. In order to clean the tympanic sinuses, more of the posterior ear canal wall is removed, including the chordal eminence and the bone inferior to the chorda toward the hypotympanum

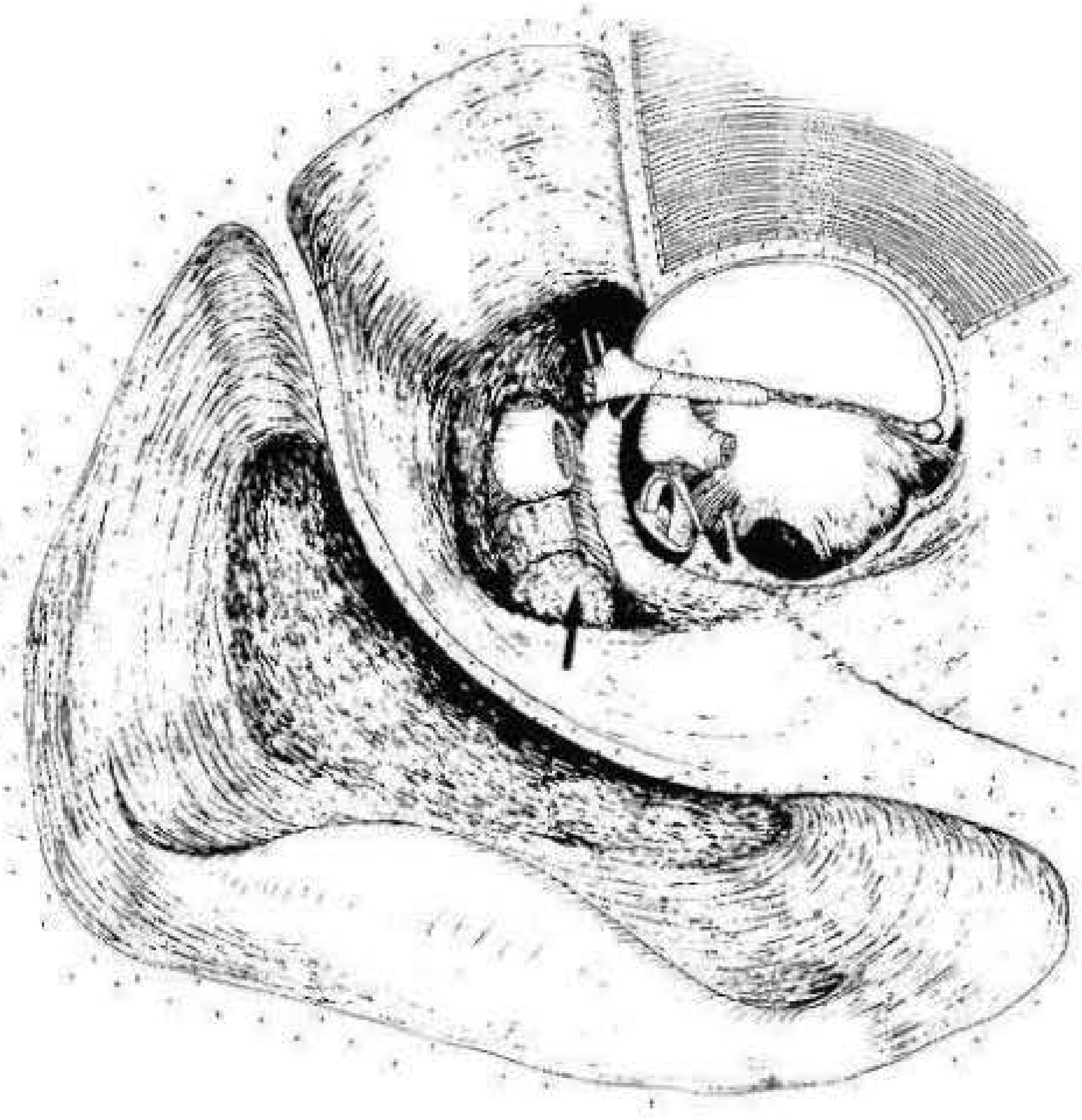


Fig. **558** Mastoidectomy is further elaborated. The bony ear canal wall is extremely thinned and displaced further posteriorly, but remains widely intact laterally. The "new" ear canal goes up to the mastoid tegmen. *Reconstruction of the cavity:* An autogenous incus is placed on the stapes. Farrior places the malleus head in the attic, possibly with a piece of bone to maintain a bony annulus. A piece of free temporalis muscle is placed in the facial recess, behind the bridge to prevent retraction (arrow)

Reconstruction of the Anterior Atticotympanotomy and Mastoidectomy

Farrior considers this technique a closed technique, and hopes for repneumatization of the mastoid cavity. By placing the resected malleus head over the lateral semicircular canal, Farrior attempts to achieve support — a form of bridge — for the fascia, and also to maintain a certain depth and ventilation of the attic. However, ventilation of the mastoid cavity can only take place superior to the malleus head (Fig. **558**). A further piece of bone can be placed over the lateral semicircular canal. Within the mastoid cavity, behind the ear canal wall, Farrior places a piece of temporalis muscle as a free graft (Fig. **558**) in order to prevent retraction into the cavity.

The drum, the attic, and most of the denuded bone are then covered by fascia as an anderlay graft. The drum and the lateral attic wall are covered as a sandwich graft with a free ear canal skin graft placed onto the fascia graft (Fig. **559**).

Farrior recommends this form of mastoidectomy in cases with attic or sinus cholesteatoma with a poorly pneumatized zygomatic region and a well-pneumatized mastoid process. Farrior usually performs the anterior atticotympanotomy first, and then the transcortical mastoidectomy.

In the present author's opinion, this approach is very flexible, because the posterior mastoidectomy can be avoided if a small cell system is present and the anterior atticotomy can be simply extended in a posterior direction as a canal wall–down procedure, i. e., an atticoantrotomy.

Although Farrior's intention is to achieve a ventilated attic, it is the author's opinion that the anterior attic will usually be obliterated by the presence of the malleus head, and this technique must therefore be considered more as a canal wall–down than a canal wall–up technique, especially since the bony ear canal wall is displaced. The residual ear canal is situated between the antrum and the aditus ad antrum, leaving the attic uncovered. One can imagine that adhesions in the attic will soon close off the superior ventilating route to the mastoid cavity (Fig. **560a**) along the tegmen tympani. The inferior ventilating route through the facial recess has already been closed off with muscle.

The consequence of this inability to ventilate the mastoid cavity leads, in the present author's opinion, to obliteration of the mastoid cavity, with complete and permanent closure of the connection between the aditus and the antrum. It is difficult to imagine what benefit good ventilation of the cavity might have for hearing in cases of a displaced bony ear canal wall (Fig. **560b**).

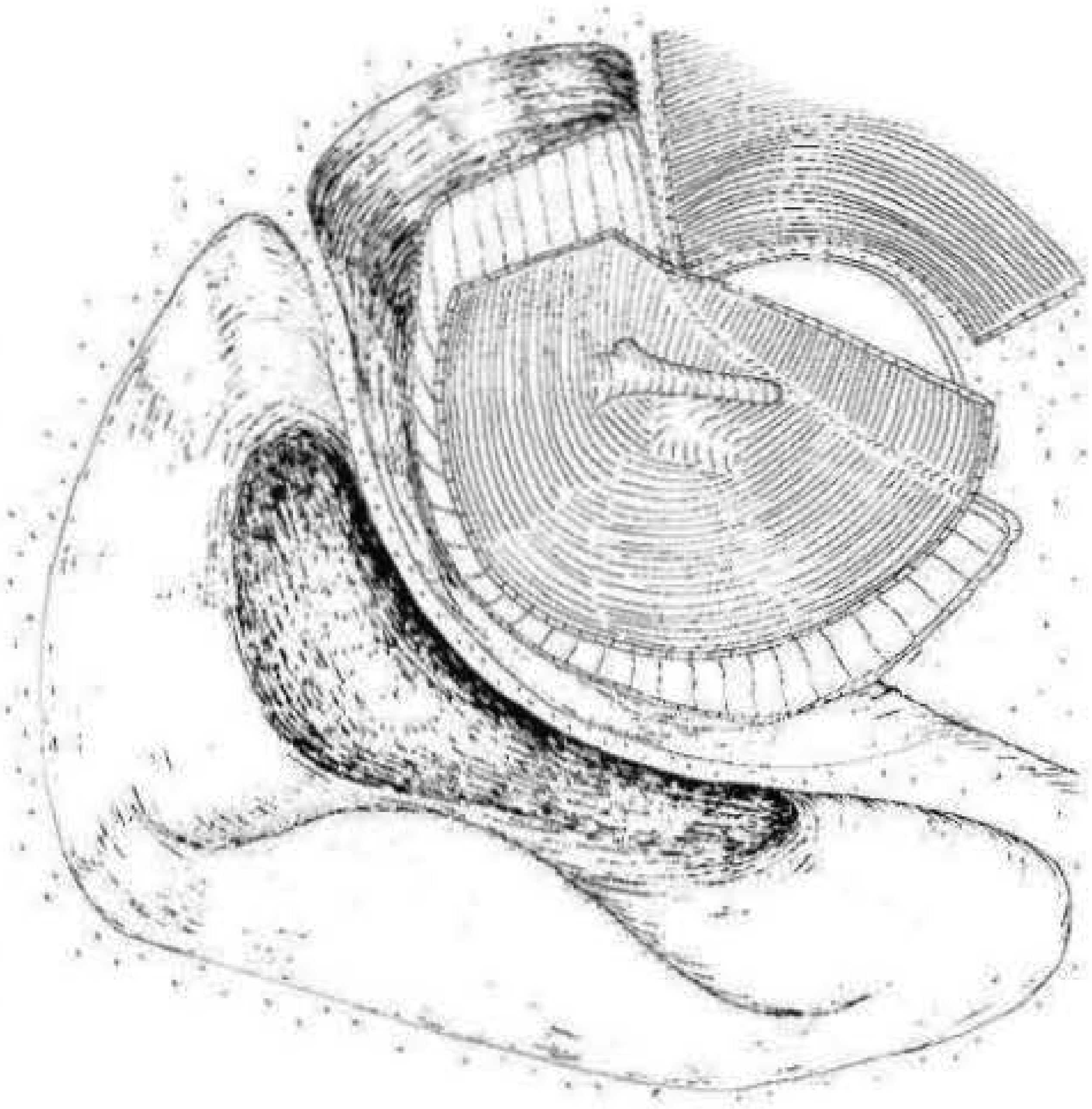


Fig. **559** **Reconstruction of the attic.** Reconstruction with fascia as an underlay graft covering the incus, the malleus head, and the cortical bone, in order to pneumatize the attic and the mastoid cavity. Fascia covers the bony ear canal. Over the drum region and the attic region, the free ear canal skin graft is placed using a sandwich technique

Firm obliteration of the posterior mastoidectomy and closure of the antrum can be performed using pieces of bone, either placed over the lateral semicircular canal alone or supported by cartilage. Superiorly or anteriorly pedicled muscle flaps can be placed in the lateral part of the cavity (Fig. **561**).

Bonding and Hinrichsen (1989) have used the technique described by Farrior with widening of the ear canal, anterior atticotympanotomy, and posterior mastoidectomy with obliteration of the cavity using bone chips and muscle flaps. One year after surgery, they achieved a satisfactory result in 40 out of 47 ears. Minor retraction pockets under the preserved ear canal were detected in only five ears, and these were selfcleaning. However, during the postoperative follow-up period of 2–7 years, an increasing number of ears developed retraction pockets or recurrent cholesteatoma, and 15% required revision due to recurrent cholesteatoma. In addition, 23% developed retraction pockets under the preserved ear canal wall, despite obliteration. This high recurrence rate indicates that obliteration with mainly soft tissue behind the preserved ear canal wall is not adequate, because the muscle will atrophy and retract. It is important to place solid tissues (Fig. **561**), i. e., bone chips supported by bone paté,

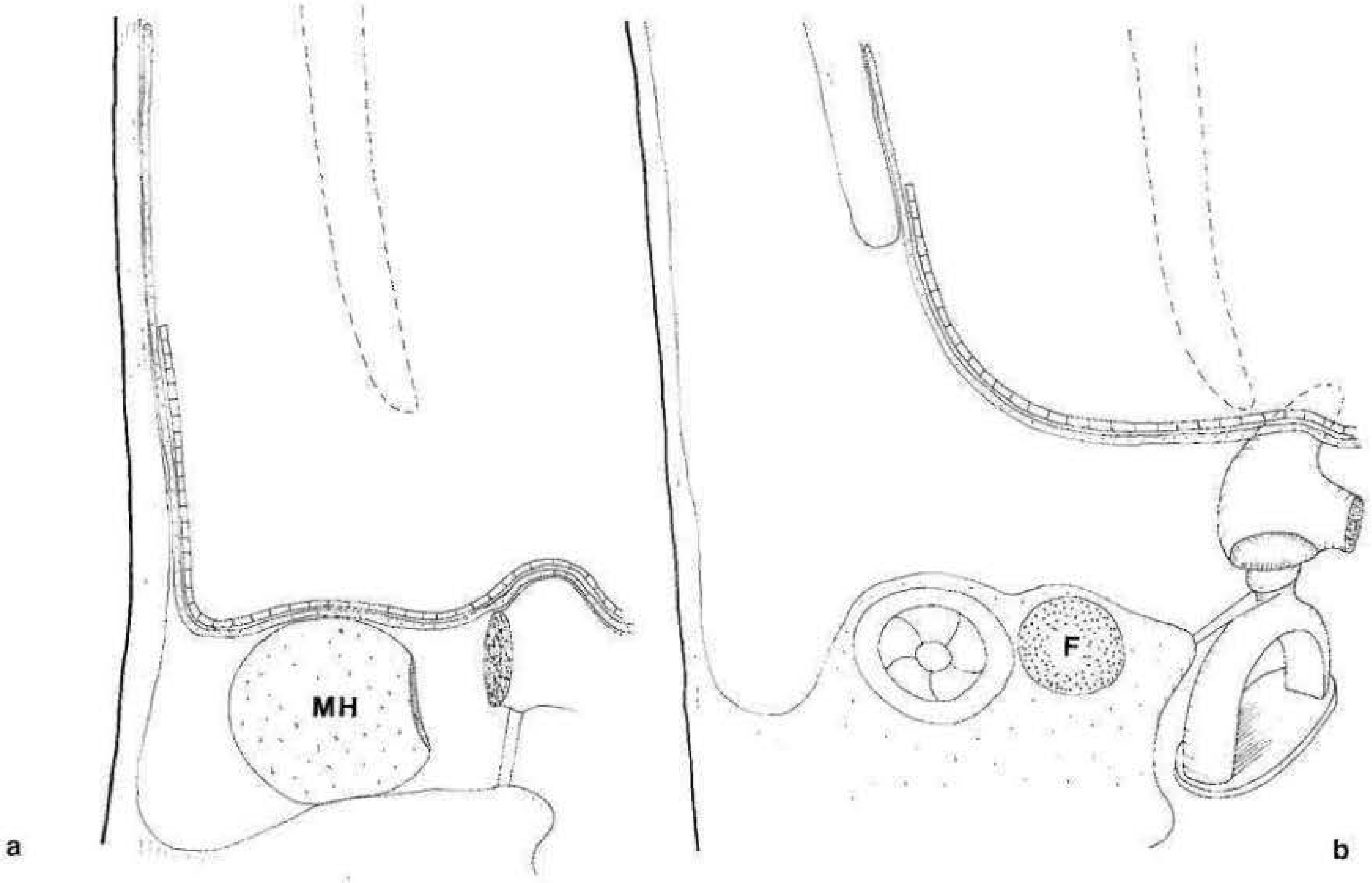


Fig. **560** **Side view of the reconstruction of the anterior atticotympanotomy. a** At the level of the malleus head, there is no ear canal, and the fascia is placed on the tegmen tympani and mastoid tegmen. It is supported by the inserted malleus head (MH) and the remnant of the malleus handle. It is evident that ventilation through the attic can not be good. The position of the original superior ear canal is indicated by dashed lines. **b** Posterior displacement of the ear canal wall at the level of the antrum and the stapes in relation to the original position (dotted). The new ear canal is positioned far posteriorly. Covering with fascia and epithelium in not solid and a retraction into the antrum and mastoid cavity is a possibility. F: facial nerve

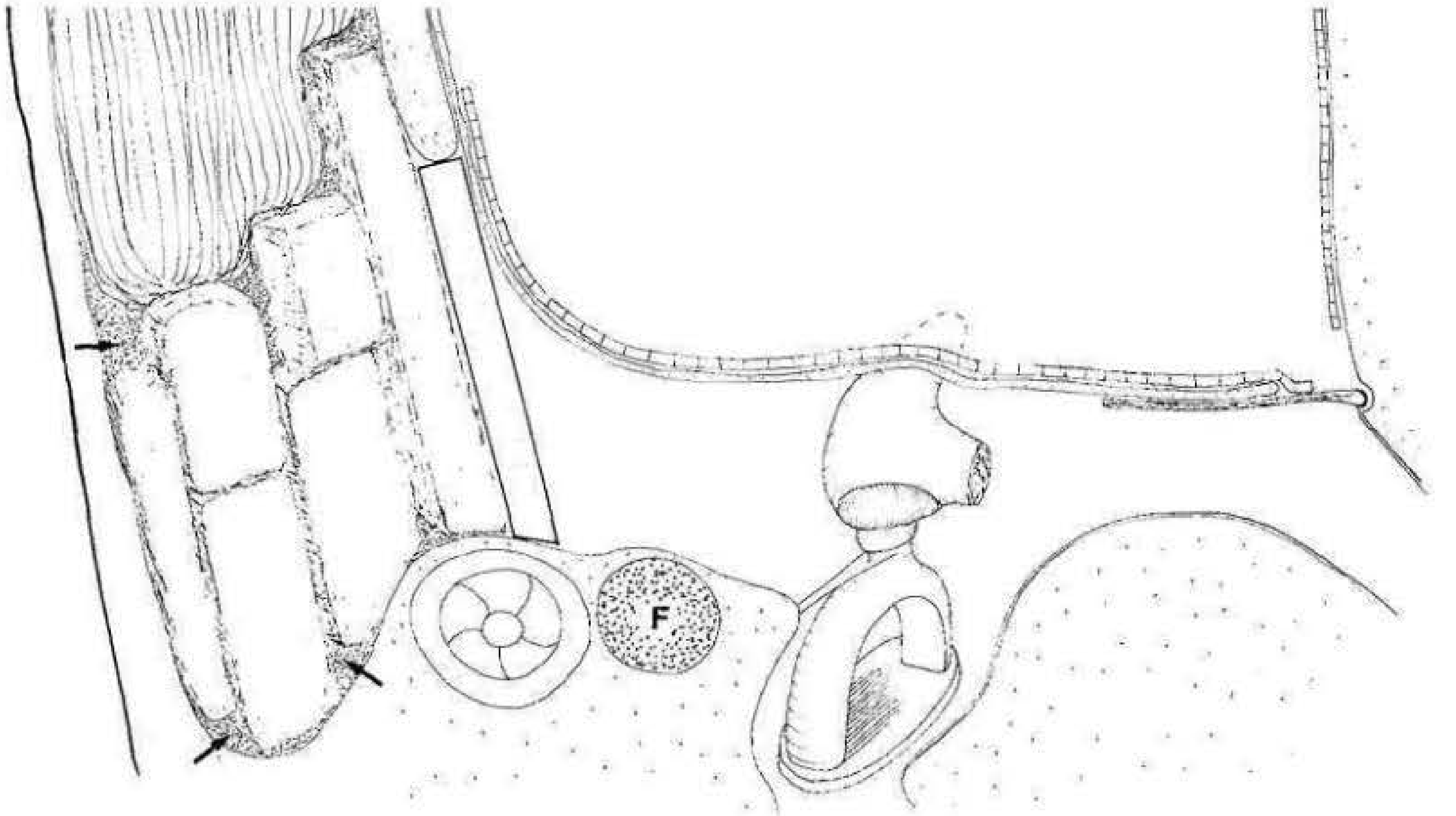


Fig. **561** Proposed obliteration of the anterior atticotomy with a posterior mastoidectomy, using large and small pieces of cortical bone and bone paté in between (arrow). A solid closure behind the displaced bony bridge and the lateral ear canal can be created, and the lateral part of the cavity can be obliterated with muscle. Cartilage is used close to the tympanic cavity. Retraction of the drum will not do any harm, because it will retract down to the facial nerve and lateral semicircular canal or pieces of cartilage, into the attic and aditus and the soft tissue behind. This study indicates that repneumatization of the mastoid cavity, as suggested by Farrior, is very difficult to achieve.

The Antrum Exclusion and Attic elimination On-Demand Technique (Olaizola)

Olaizola (1985, 1988) described a similar technique to that of Farrior in an attempt to eliminate the inconvenience of the cavity and avoid or reduce the risk of retraction cholesteatoma. There are three variations of the antrum exclusion and attic elimination techniques.

1. Using an endaural approach and a transmeatal route, the bone covering the anterior attic and the posterior attic is removed. If the pathology is only located in the attic, and can be safely removed, no further surgery is performed, and the aditus is covered with a cartilage plate, thus eliminating the attic from the aditus ad antrum (Figs. **562, 563**). This procedure is in fact an atticotomy.
2. Continuing with the same procedure in a posterior direction from the attic to the antrum, which is then exposed, hence performing an atticoantrotomy (Fig. **564**). The atticoantrotomy opening

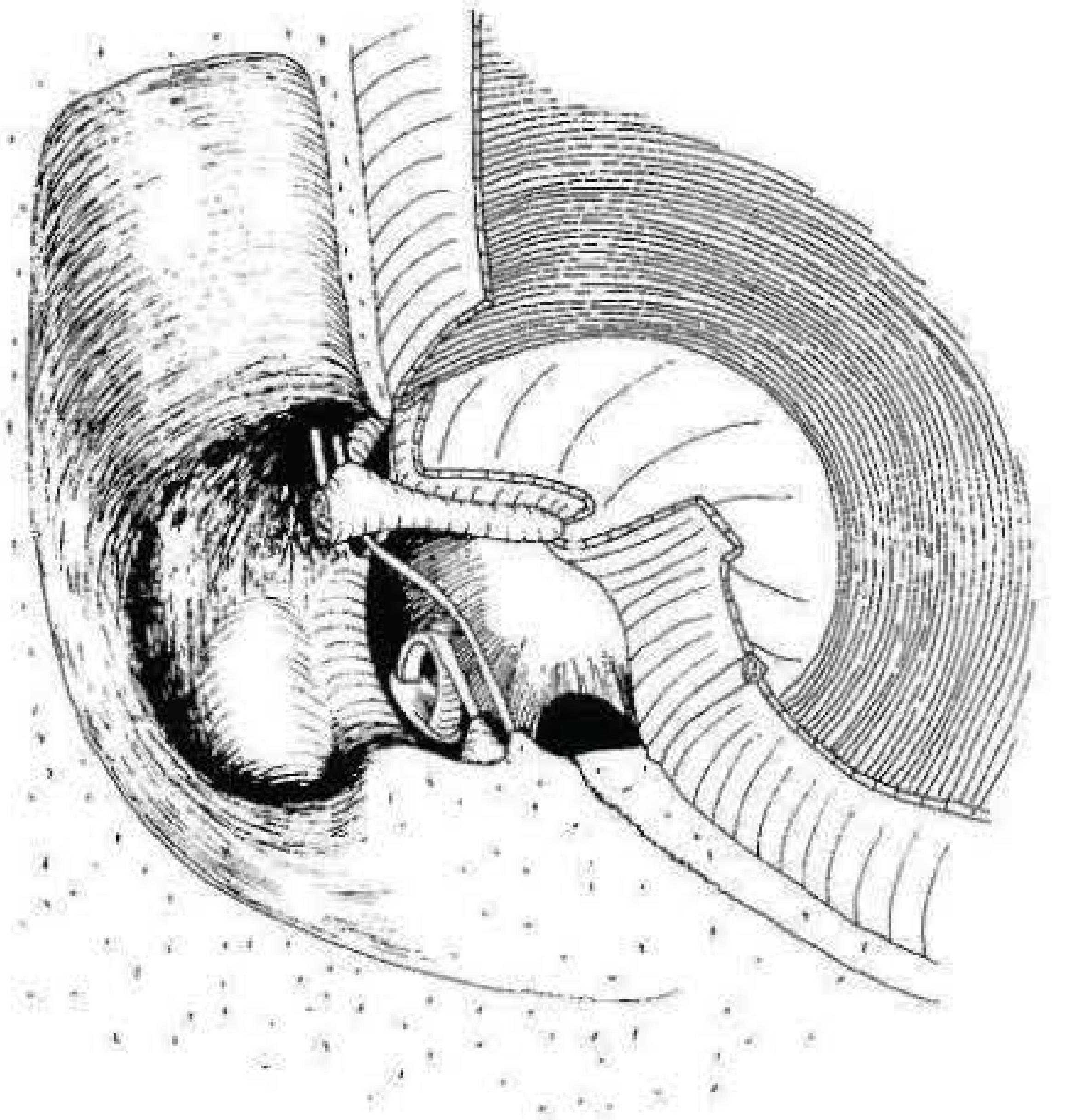


Fig. **562** **The antrum exclusion and attic elimination on-demand technique.** An atticotomy is performed in the endaural approach with the transmeatal route following the posterior extension of the cholesteatoma. The defective incus is removed, and the malleus head is extruded. If the cholesteatoma is removed, no further surgery is performed.

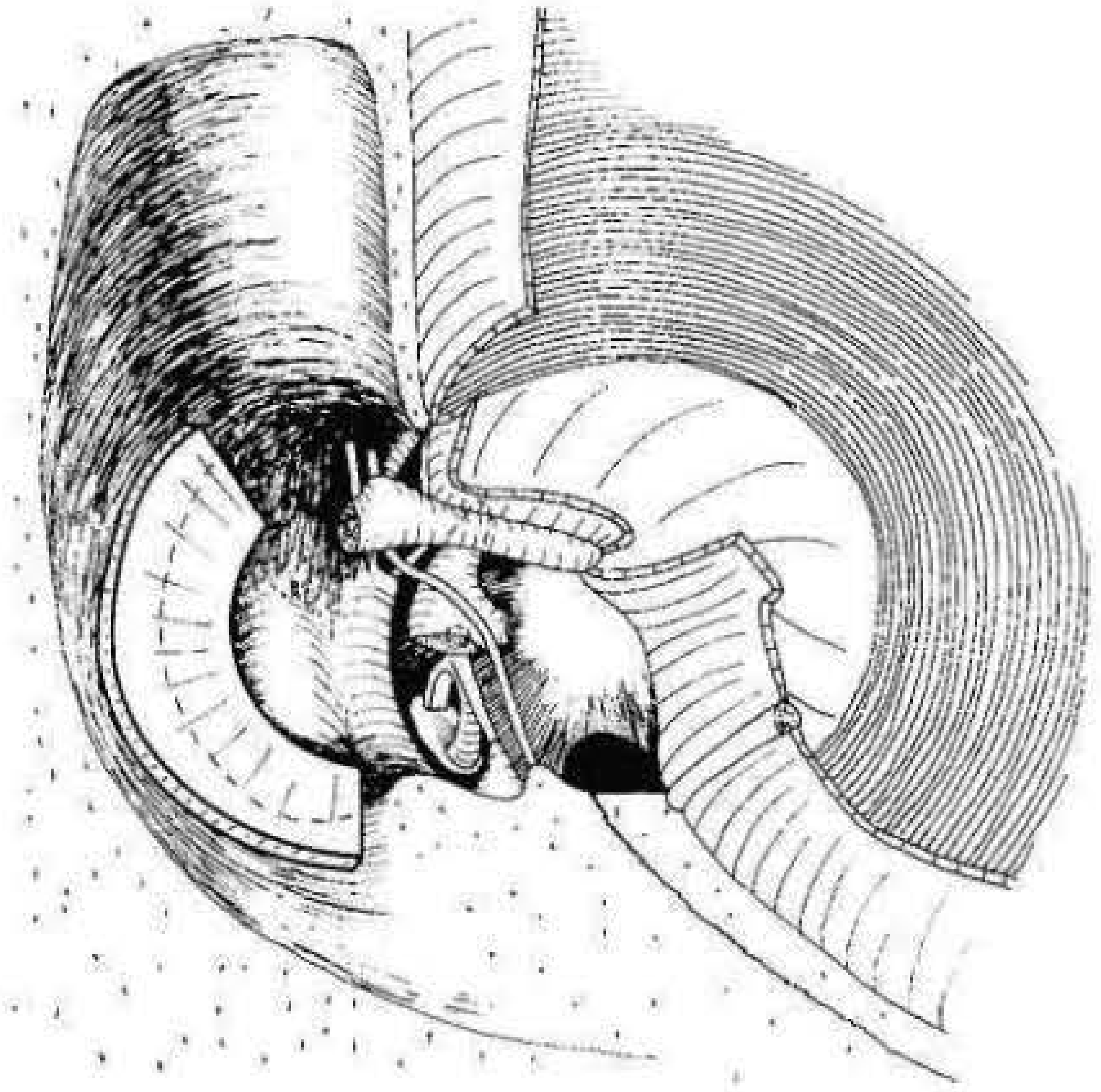


Fig. **563** The connection between the attic and the aditus ad antrum is closed with a cartilage plate, the ossiculoplasty is performed with an incus, and fascia covers the tympanic cavity, the resected malleus handle, the medial wall of the attic, and the cartilage plate with the denuded bone. The attic is an open space, and the antrum is supposed to be ventilated

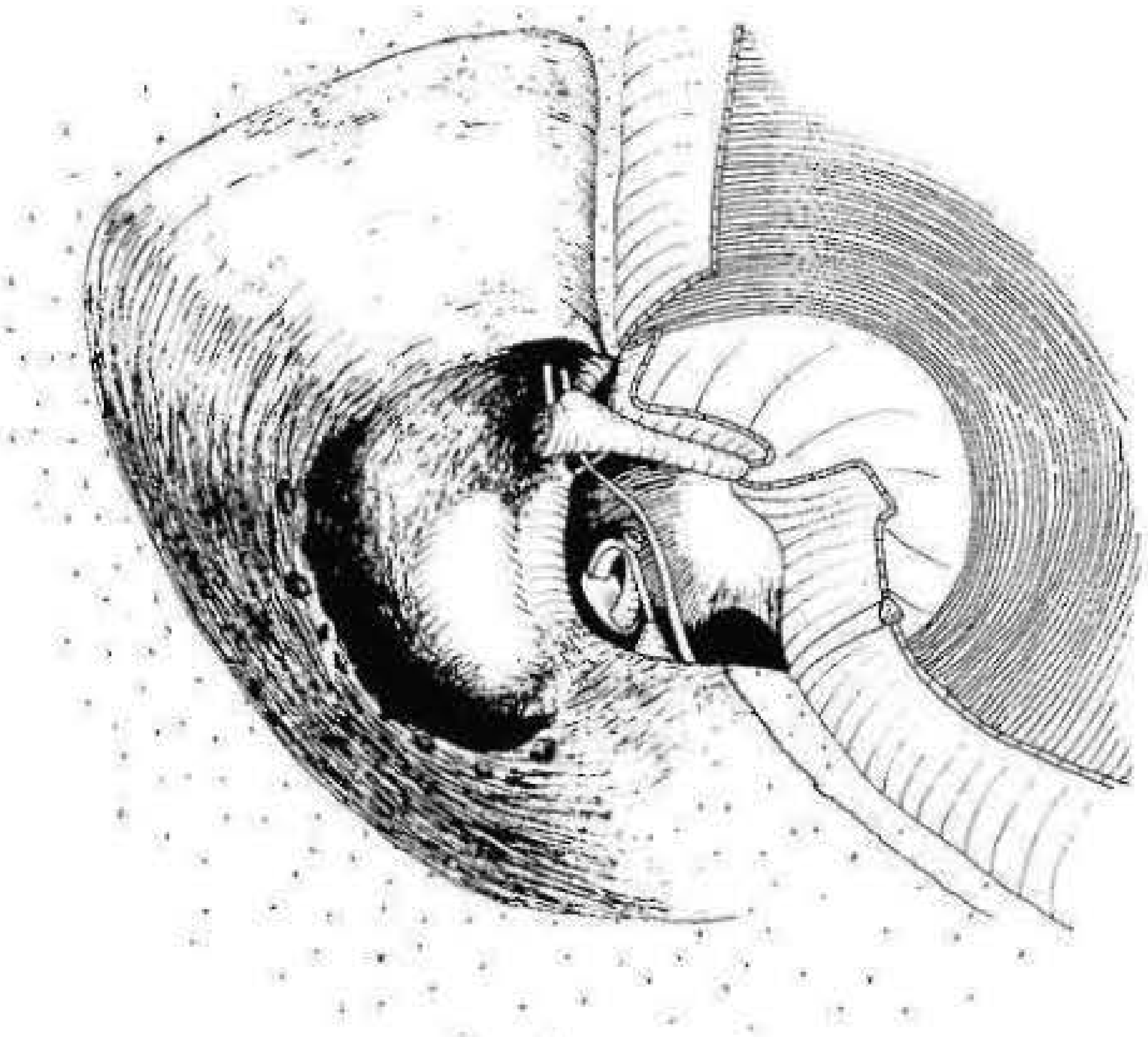


Fig. **564** Following the cholesteatoma extension posteriorly, a wide atticotomy and aditotomy as well as antrotomy are performed, exposing the entire antrum and aditus, the mastoid tegmen, and the tegmen tympani

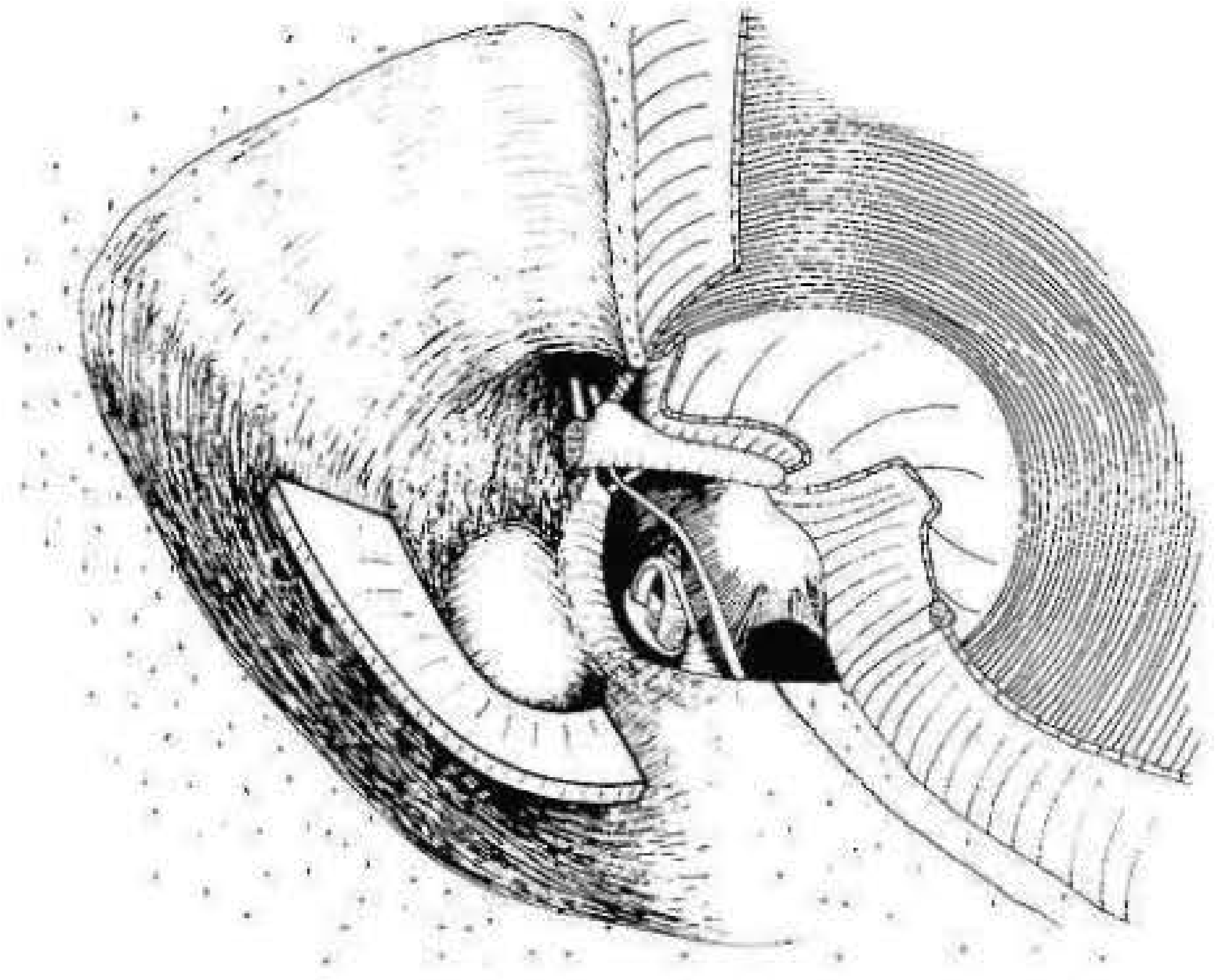


Fig. **565** **Reconstruction in the antrum exclusion method** consists of covering the connection between the aditus ad antrum and the antrum with a large piece of cartilage. The attic and aditus ad antrum will be open spaces covered with fascia

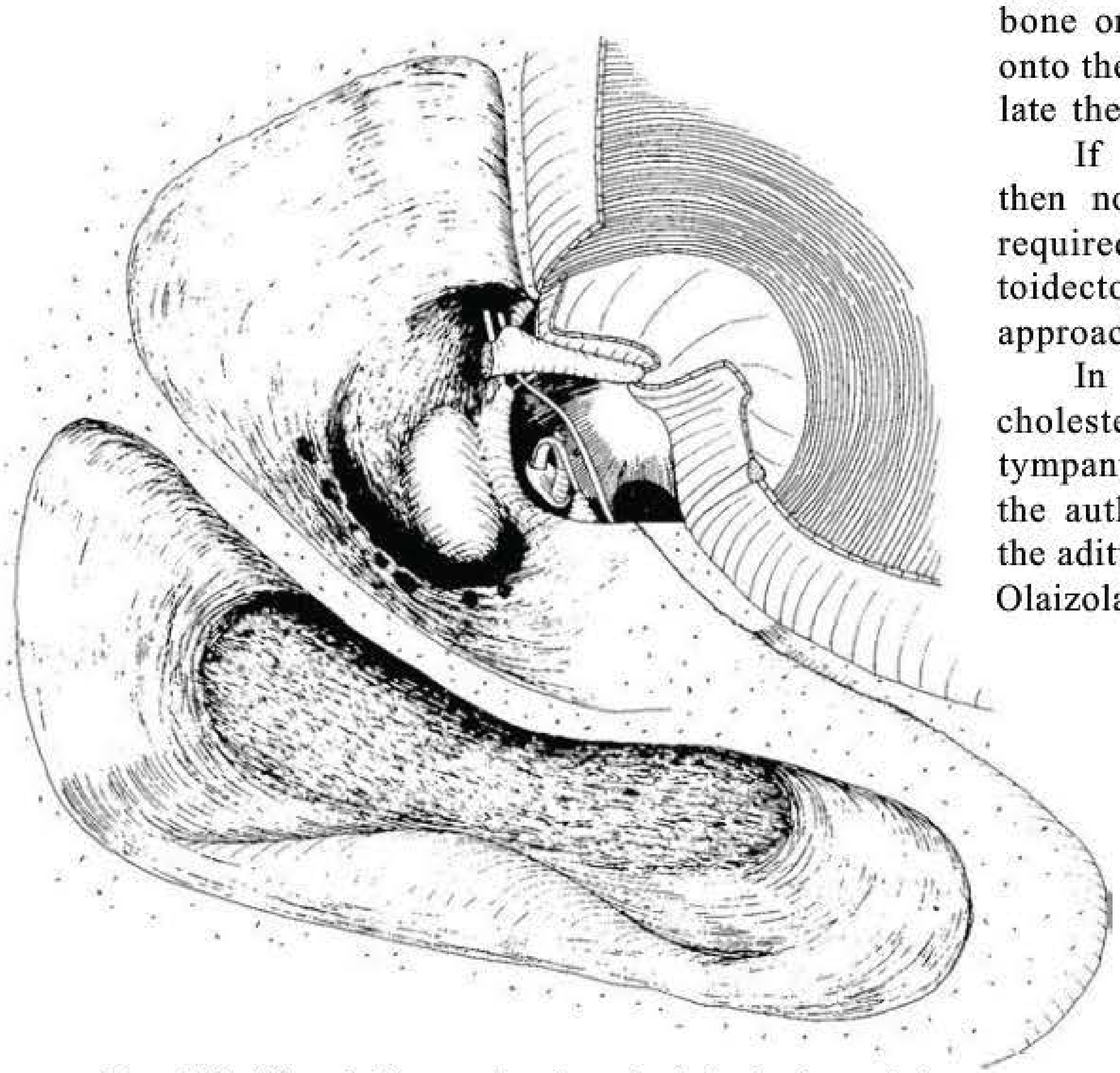


Fig. **566** After further extension of cholesteatoma into the mastoid process after enlarging the ear canal and performing atticoantrotomy, the preserved ear canal will not be displaced further posteriorly. A separate cortical mastoidectomy is performed behind the displaced bridge, and the cholesteatoma is removed

is then covered with a large piece of cartilage, eliminating the attic and aditus and part of the antrum (Fig. **565**).

3. If the cholesteatoma continues further in a posterior direction, then no more bone is removed from the metal side of the ear canal. The displaced ear canal wall is preserved, and a transcortical mastoidectomy is performed behind the preserved bony ear canal (Fig. **566**). The opening is then covered with cartilage, again eliminating the aditus and part of the antrum (Fig. **567**).

In all three techniques, an endaural approach is applied, with the creation of large superior and inferior ear canal skin flaps. The atticotomy and antrotomy are performed in a transcanal fashion with careful drilling of the bony annulus, starting anteriorly and continuing posteriorly, exposing as much of the lateral attic wall as necessary. If the cholesteatoma only reaches the antrum, the surgery stops, and reconstruction with a cartilage plate is performed in such way that the attic becomes an open cavity (Fig. **563**). If the cholesteatoma extends far posteriorly, the transcanal widening of the ear canal is continued, opening the aditus and antrum (Fig. **564**), and once the cholesteatoma is removed, a bone or cartilage piece is placed in the aditus and onto the remaining bone in order to separate and isolate the cavity.

If the cholesteatoma continues posteriorly, then no further enlargement of the ear canal is required, but a transcortical posterior mastoidectomy is necessary, using the endaural approach.

In this technique, the problems of residual cholesteatoma in the anterior attic and posterior tympanum are reduced. However, it is difficult, in the author's opinion to see how the cavity behind the aditus and attic can be ventilated. In the hands of Olaizola, the techniques described are better, with

If ventilation through the tympanic isthmus is eliminated, as is the case in this technique, then ventilation must take place via the hypotympanum, apical cells, and infralabyrinthine cell tracts (Olaizola 1985, 1988, 1989).

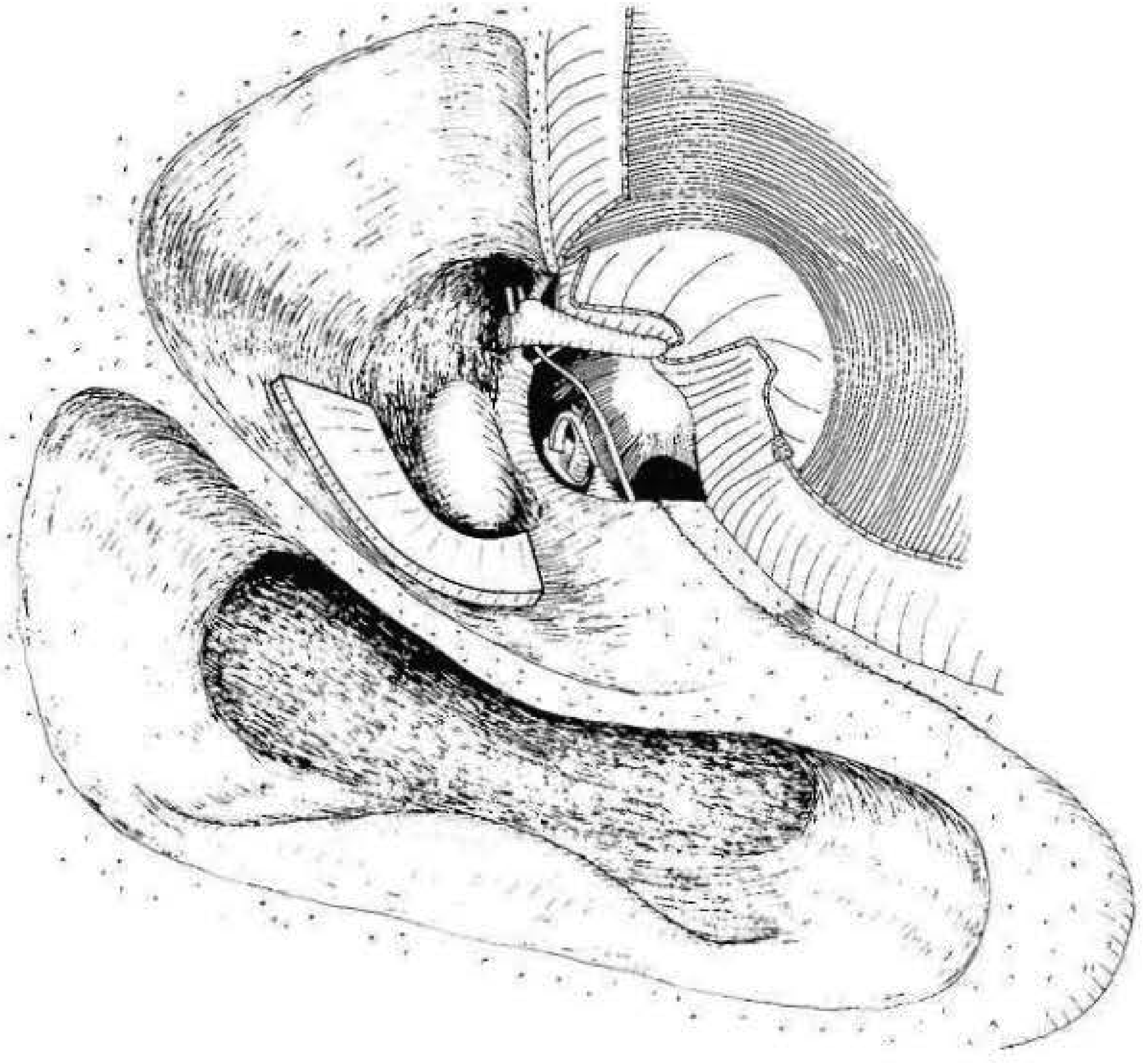


Fig. 567 **Reconstruction of the posterior displaced ear canal wall.** A cartilage plate is placed between the mastoid cavity and the tympanic region. The aditus ad antrum and attic will be covered with fascia, like open cavities, and the mastoid cavity is supposed to be pneumatized

only 10% failures, when compared with obliterative techniques, with 15%, and closed techniques with 20% failures.

The Wide External Auditory Canal Technique (Bellucci)

Bellucci (1973) uses a similar technique to Farrior — *the wide external auditory canal technique.* The principle is to achieve extreme widening of the ear canal whilst still preserving the bridge. In this method, an atticotomy and atticoantrotomy is performed, using the retroauricular approach and the transmeatal route. If the cholesteatoma extends further posteriorly, then a separate cortical mastoidectomy is performed, and the posterior ear canal wall is preserved in a more posterior position than in conventional cortical mastoidectomy. The wide external auditory canal technique affords excellent exposure of all regions of the middle ear, and provides sufficient space for all reconstructive procedures. Tissue, essential for a reconstructive procedure, can be preserved by starting the operation in the external auditory canal. In Bellucci's technique, the most critical region is exposed first, and it is possible to assess the degree of middle ear damage early in the operation. This early recognition has an important influence on the remaining course of the surgery, which is extended step by step from the middle ear into the epitympanic space, and finally into the antrum and mastoid.

11 Transcortical Canal Wall–Down Mastoidectomy

A canal wall–down mastoidectomy can be performed through the transcortical route, described in this chapter, or the transmeatal route, described in chapter 12. Both routes result in an atticoantrotomy, a conservative radical, or a classical radical operation.

For the *transcortical* route (Fig. **24**) a cortical mastoidectomy with antrotomy is performed, leaving the bony ear canal intact during the first phase of the operation, retaining the possibility of preserving it and performing a canal wall–up mastoidectomy or one of its modifications. The bony ear canal wall is usually removed after the antrotomy and after locating the lateral semicircular canal. This is called the "outside-in" method.

The *transmeatal* route starts in the ear canal, either laterally and continuing medially, the so-called "outside-in" method (Fig. **25**), or it starts medially with an atticotomy and continues laterally and in a posterior direction to the antrotomy and mastoidectomy. This latter "inside-out" method is also called a retrograde mastoidectomy (Fig. **26**).

Historical Remarks

Transcortical mastoidectomy is a modification of the Schwartze simple mastoidectomy as suggested by von Tröltsch in 1873 to cure chronic disease. The name "radical operation" was introduced by von Bergmann (1889) for cases with removal of the posterosuperior bony ear canal wall. In 1890, Zaufal described in detail the technique of radical operation that left all areas of chronic disease exposed, including the tympanic cavity. Subsequently, Stacke (1893) described a plastic meatal skin flap, and the radical operation is referred to either as the Zaufal or as the Stacke operation.

Körner (1899) suggested that, in certain cases of chronic otitis, the tympanic membrane and ossicles could be left in place during the radical operation in order to preserve good hearing. Bondy (1910) finally described the indications for, and technique of, a modification of the radical operation for cases in which the pars flaccida perforation was accompanied by an intact pars tensa. Without disturbing the intact pars tensa or the tympanic cavity and ossicles, the posterosuperior bony wall was taken down, thus exteriorizing the attic and antrum cholesteatoma into a permanently open modified radical cavity that could be kept clean safely through the external meatus. Despite the very clear indications suggested by Bondy (1910), this modification of the radical mastoid operation was very slow to receive widespread acceptance, and the Bondy operation was not even mentioned in a standard text of otologic surgery as late as 1929 (Kopetsky 1929). At that time, the aim of surgery was to produce a safe ear and, incidentally, a dry ear, but not a functioning ear. With the introduction of the one-stage fenestration operation in 1938 by Lempert, surgeons began to be more concerned about preserving hearing, and the Bondy operation became popular. Baron (1949) pointed out that the Bondy operation was more often indicated for cases of chronic otorrhea with cholesteatoma than was the classic radical operation. The further developments by Zöllner (1951) and Wullstein (1952, 1956), with the introduction of tympanoplasties to reconstruct the sound conduction system in the middle ear, further reduced the indications for the radical operation.

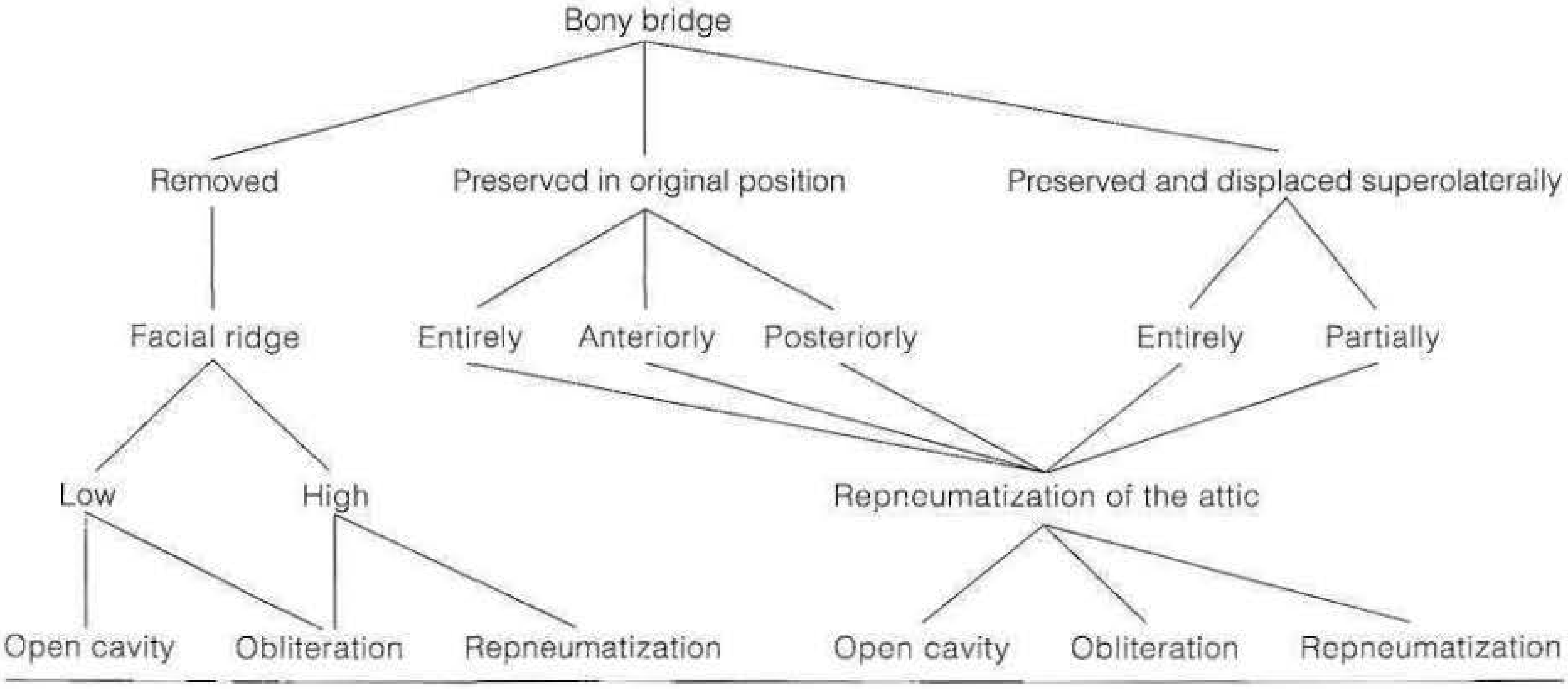
Definitions

In canal wall–down mastoidectomy, the posterosuperior bony ear canal wall is removed, either together with the *bony bridge* (Figs. **8**, **9**, **22**, **23**) or with the bony bridge being entirely or partly preserved in its original position or displaced superolaterally (Table **6**) (Figs. **48** to **50**).

In ears undergoing bridge removal, the *facial ridge,* i. e., the part of the tympanic bone covering the vertical segment of the facial nerve, can be lowered as recommended in open cavity techniques or in obliteration techniques using soft tissues, where atrophy of the muscles and retraction of the soft ear canal is expected (Table **6**). In some obliteration techniques (Nakano 1993) with hard materials such as hydroxyapatite granules or bone chips, the facial ridge remains high. In such cases, retraction needs to be prevented.

In cases with bony bridge preservation, the attic is intended to be repneumatized (Table **6**), and the bridge also supports the lateral attic wall. In addition, the bridge supports the ear drum graft in myrin-

Table **6** The bony bridge in transcortical or transmeatal canal wall–down mastoidectomies


Bony bridge
Removed
Preserved in original position
Preserved and displaced superolaterally
Facial ridge
Entirely
Anteriorly
Posteriorly
Entirely
Partially
Low
High
Repneumatization of the attic
Open cavity
Obliteration
Repneumatization
Open cavity
Obliteration
Repneumatization

goplasty and maintains the original drum level, important in ossiculoplasty. A partly preserved bridge or a displaced bridge serves the same purpose.

The mastoid cavity behind the ventilated attic can be obliterated, ventilated, or may remain open (Table **6**).

Bondy's Operation

In ears with an attic cholesteatoma, good hearing, and an intact pars tensa, the original Bondy's operation can be performed using a retroauricular or an endaural approach.

With the retroauricular approach, the basic techniques of cortical mastoidectomy are described in Chapter 4. After the lateral mastoid cells have been exenterated (Figs. **147** to **151**), the Körner's septum is removed and the antrum opened (Figs. **189** to **191**).

In attic cholesteatoma with diminished pneumatization, a large cholesteatoma occupying the entire antrum is exposed (Fig. **568**). After drilling of the overhangs along the middle fossa dura and the posterior fossa dural plates and thinning of the bony ear canal wall, the lateral half of the cholesteatoma is exposed (Fig. **569**). In order to obtain space to remove the ear canal wall, the cholesteatoma sac is opened and the cholesteatoma mass is removed, allowing the cholesteatoma membrane to be further elevated from the bony ear canal wall (Fig. **570**). Removal of the cholesteatoma mass is achieved by using a thick suction tube and a rugine. The cholesteatoma mass is reduced, and the surrounding bone is carefully polished, with removal of all overhangs from the mastoid tegmen and tegmen antri as well as from the posterior fossa dural plate.

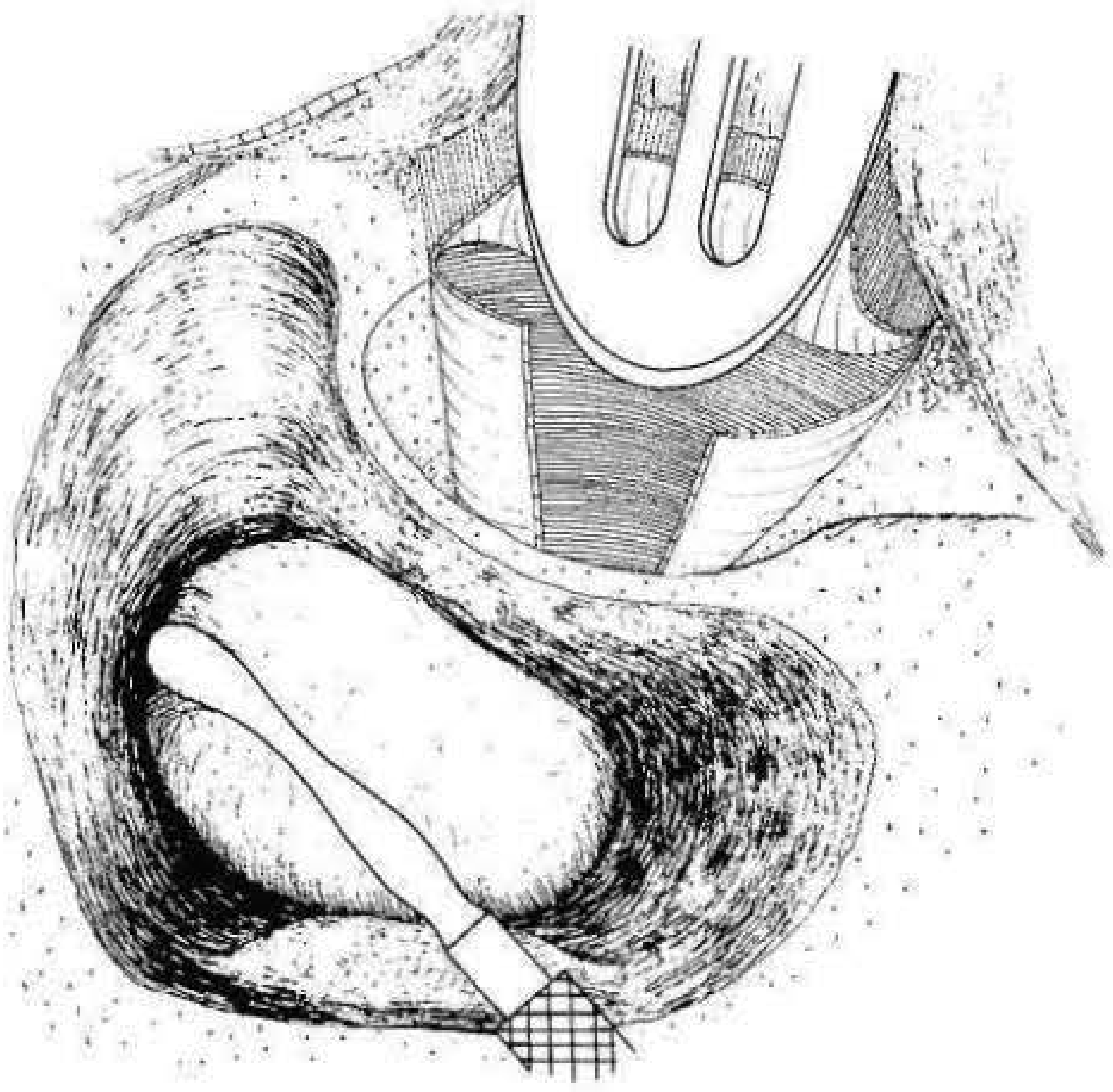


Fig. **568** **The technique of the Bondy operation.** A cortical mastoidectomy is performed using the retroauricular approach, and the ear canal skin is elevated from the posterior aspect of the meatus. The lateral mastoid air cells are exenterated, Körner's septum is removed, and the lateral part of the attic cholesteatoma occupying all the antrum is located. Using Freer's rugine, the matrix is elevated

In some cases, the cholesteatoma matrix is smooth and surrounded by a thin layer of connective tissue separating it from the surrounding

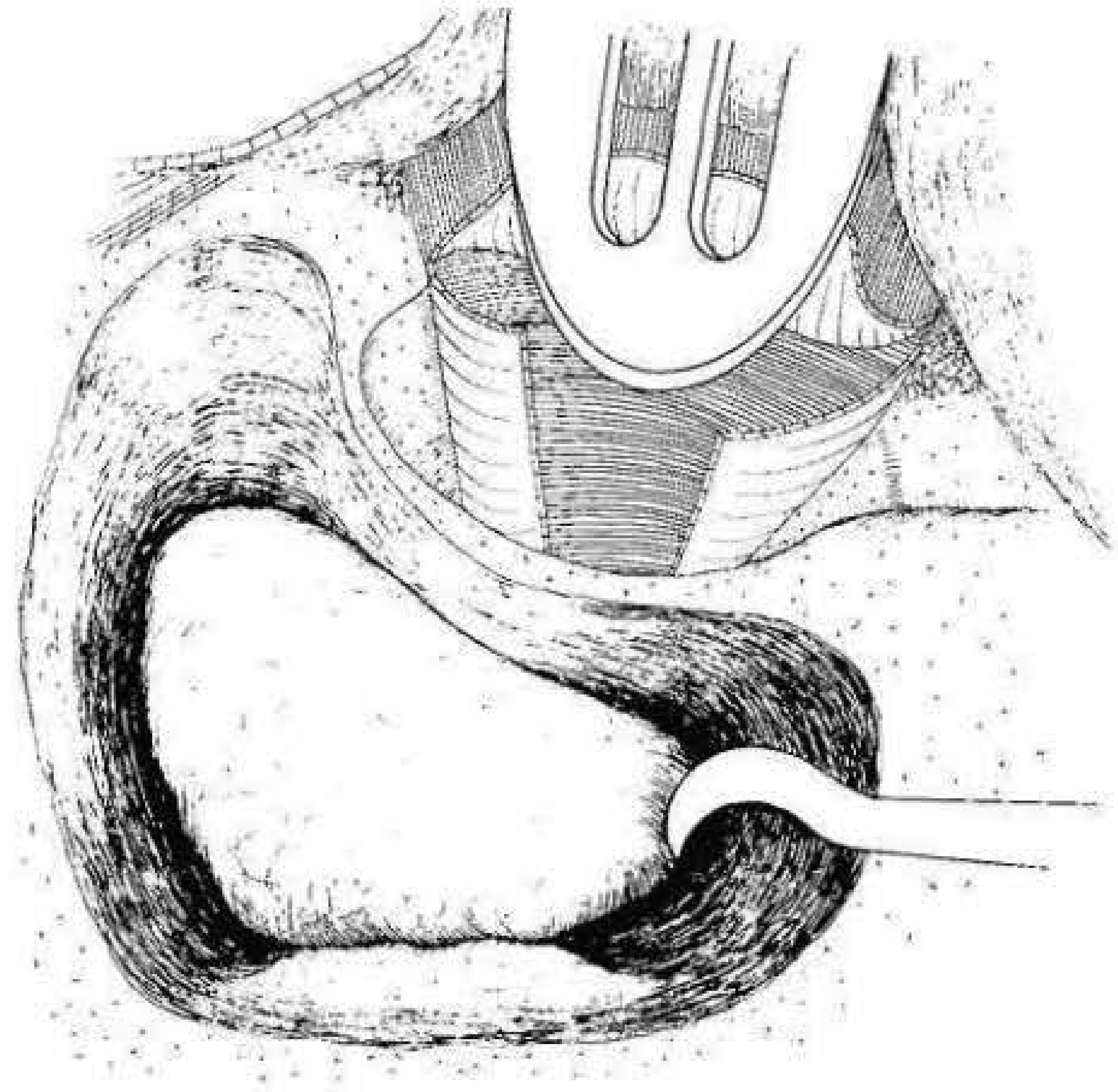


Fig. **569** The borders of the cholesteatoma are carefully inspected **and** elevated **all the** way around, with the mastoid tegmen being localized superiorly, and the sinodural angle and posterior dural plate region, as well as the bony ear canal wall, being localized posteriorly. The cholesteatoma sac has not been opened yet

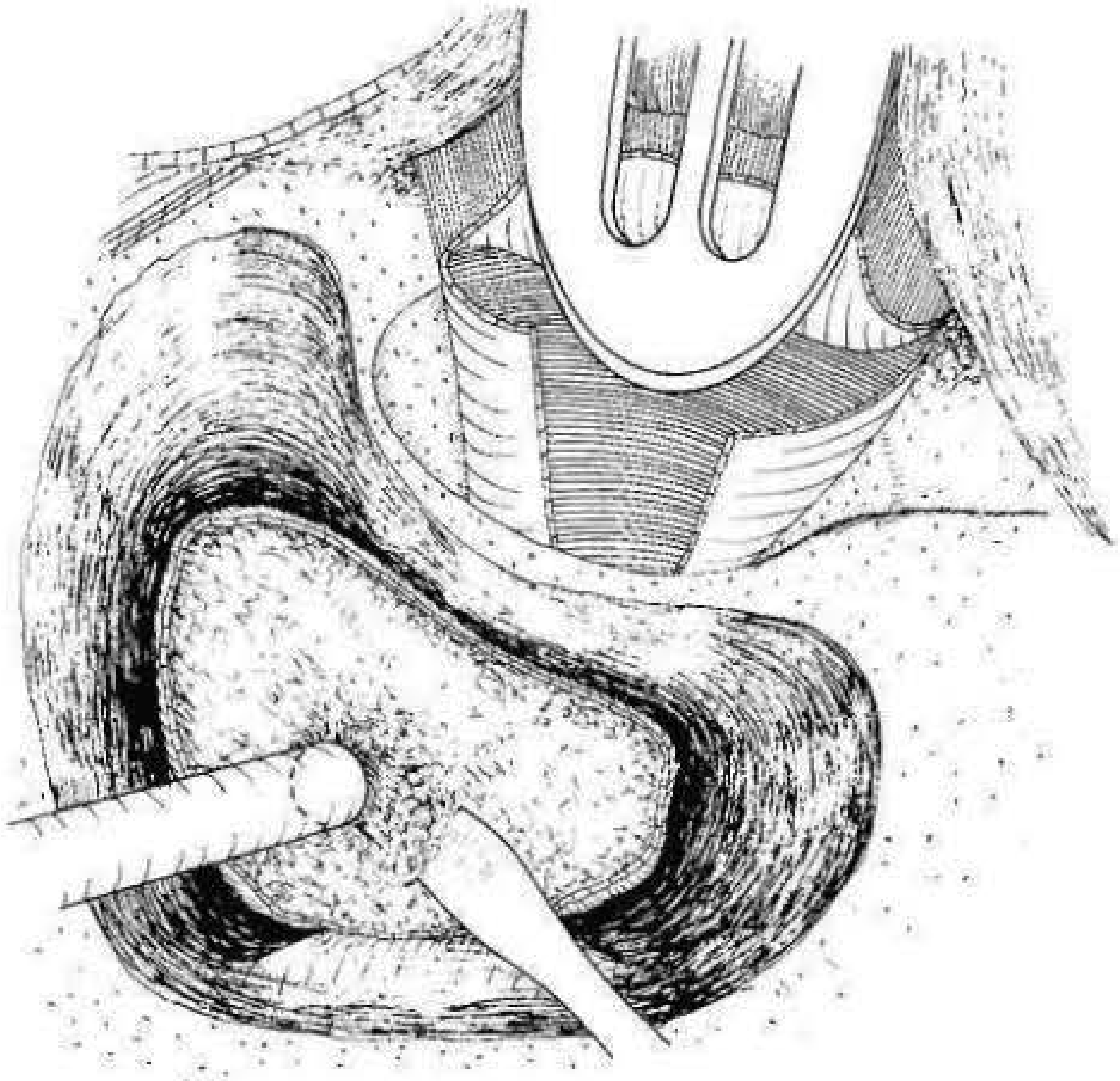


Fig. **570** The cholesteatoma sac has been opened, and the lateral half of the matrix removed. Using a large suction the cholesteatoma mass is removed inside the matrix elevating the various layers of the cholesteatoma mass using a Freer's rougine. The matrix is further elevated all the way around exposing the bony walls of the antrum and attic

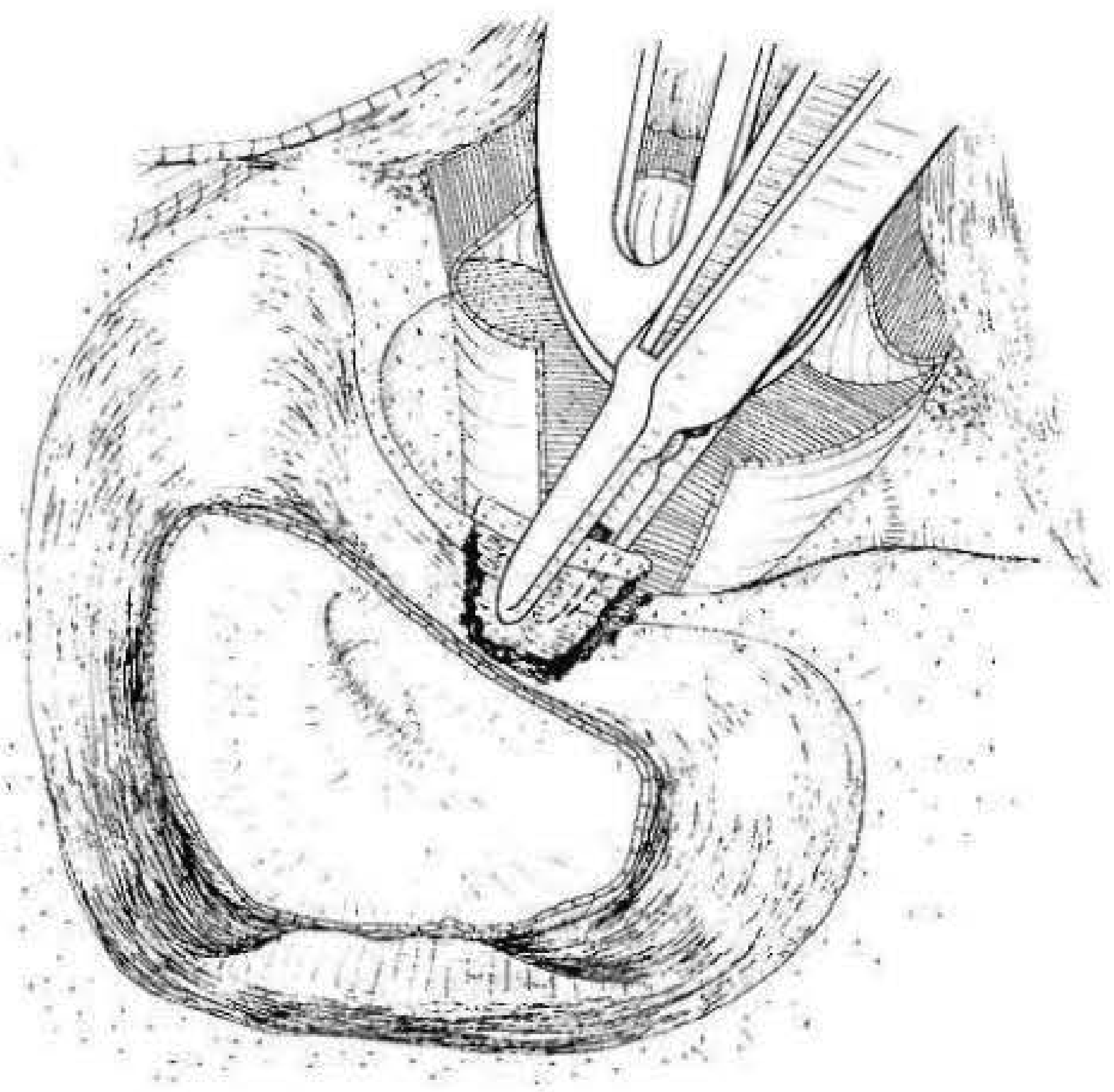


Fig. **571** The bony ear canal wall is removed using a strong rongeur, piece by piece, or using a cutting burr

sclerotic bone. Sometimes the cholesteatoma matrix is closely applied to the bone, with fingerlike extensions into small cells. Such extensions should be carefully removed as indicated in Chapter 4, Figures **219** to **239**. When the cholesteatoma mass has been completely removed either by suction or by instruments, the medial anterior borders of the cholesteatoma membrane are delineated, especially from the bony ear canal wall. After elevation of the meatal skin, the bony ear canal is removed piecemeal using a strong rongeur as far as the bridge (Fig. **571**) or until the attic perforation is reached. The rest of the bridge is removed using a curette, directed outward to avoid luxation of the incus lying under the cholesteatoma matrix (Fig. **572**). There now follows the removal of the posterior and anterior buttresses and polishing of the anterior meatal wall, so that the anterior ear canal wall continues directly into the tegmen tympani and mastoid tegmen. Posteriorly, the bony ear canal wall is removed, and the facial ridge is lowered and polished using a diamond burr. Finally the cholesteatoma membrane, which is left in place as exteriorized epidermis, is checked, especially medially, and a search is made for fingerlike ingrowth into the perilabyrinthine air cells. If such cells are invaded by cholesteatoma, they should be removed along with the matrix; a smaller area of the matrix is then left in place (Fig. **573**).

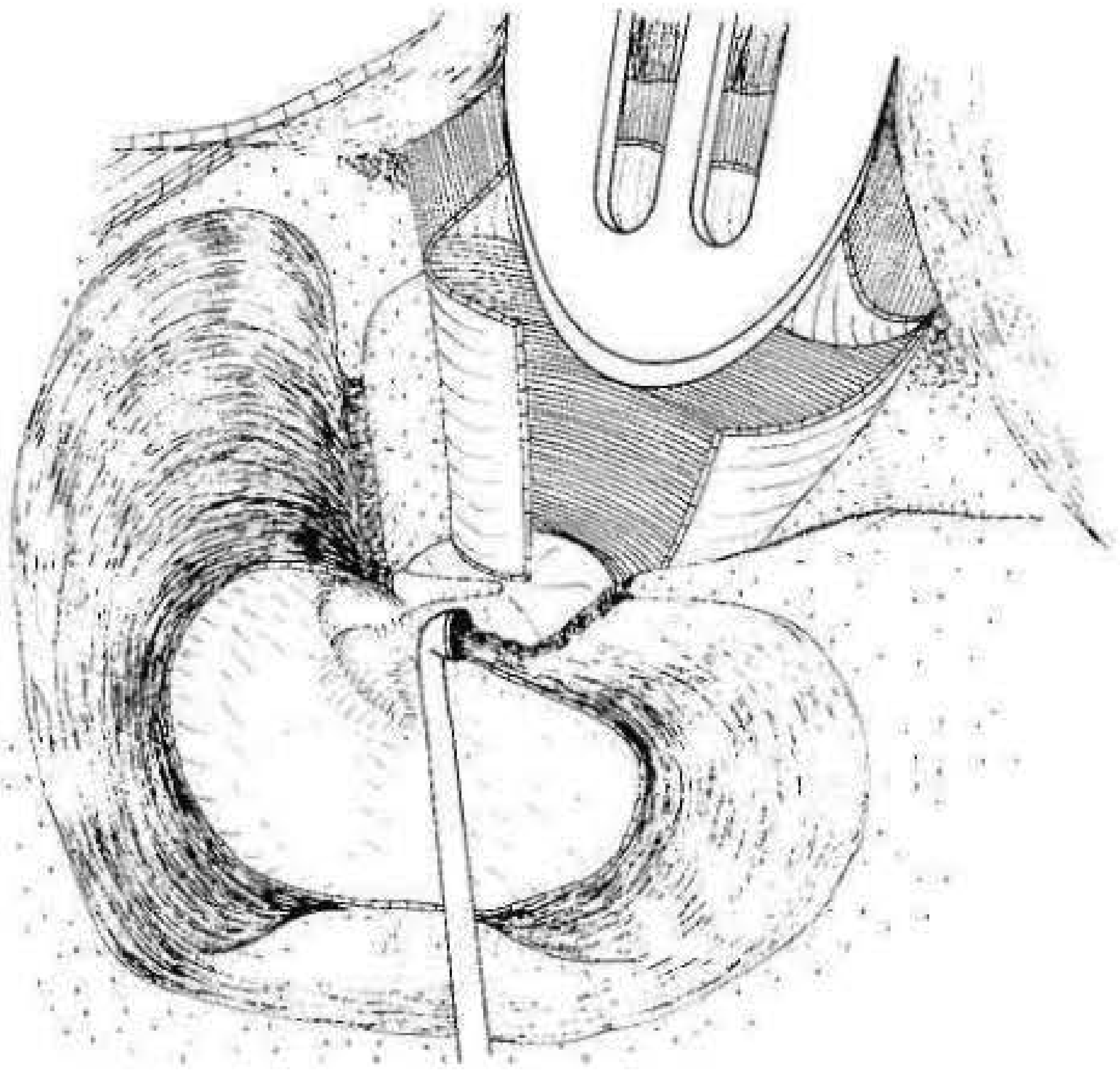


Fig. **572** Remnants of bony ear canal wall are left along the zygomatic region and along the facial ridge. The anterior buttress is carefully removed with a curet, as is the posterior buttress, exposing the medial wall of the attic retraction, the head of the malleus, and the incus body. Extensive drilling of the borders of the ear canal wall now takes place superiorly and at the facial ridge

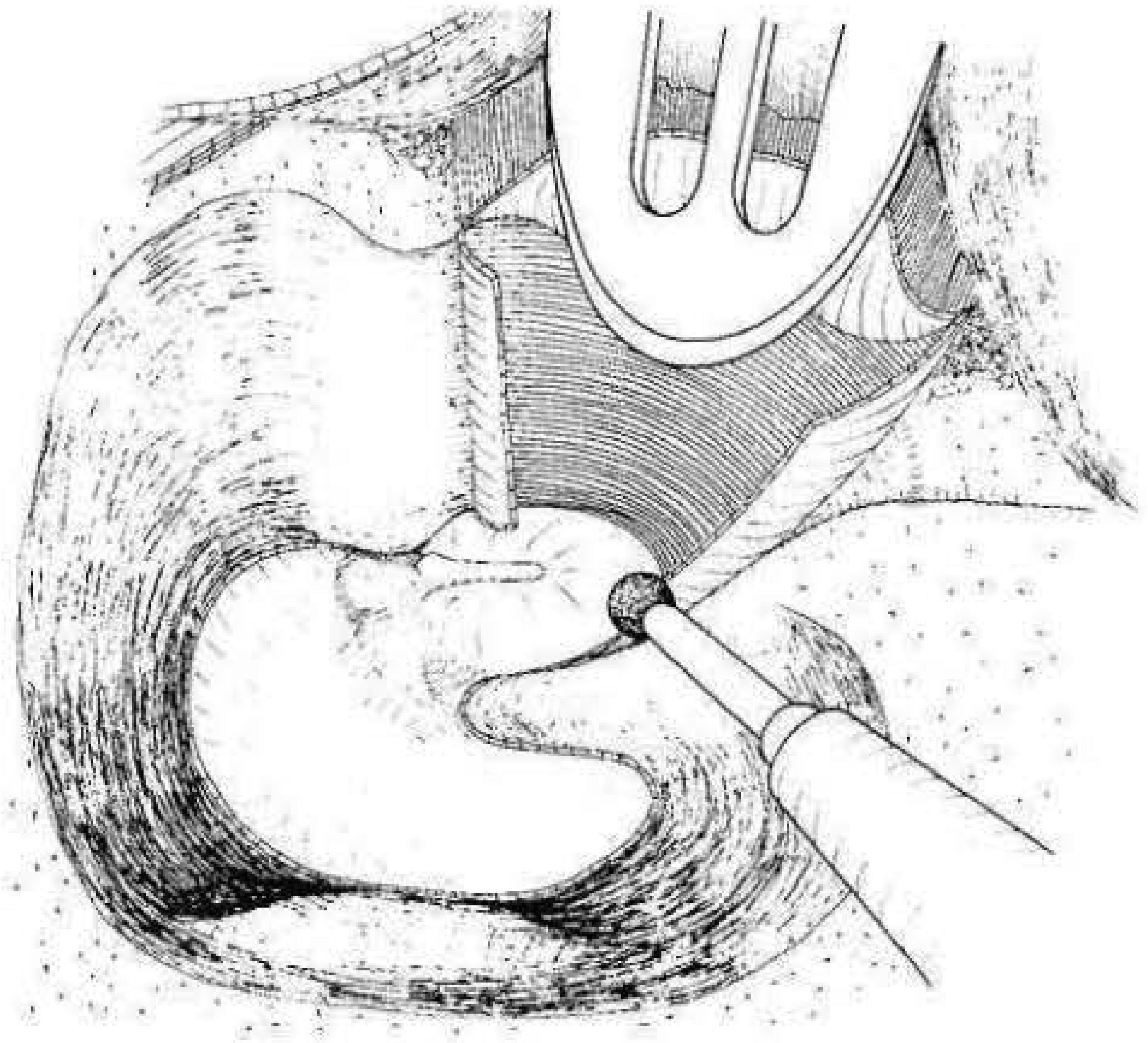


Fig. **573** Anteriorly, the ear canal wall has been smoothed without overhangs, with a good transition from the anterior ear canal wall to the mastoid tegmen. Posteriorly, the facial ridge has been lowered considerably and made smooth using a diamond burr, and the cavity is now ready to be reconstructed

Reconstruction in Bondy's Operation

The skin flaps are replaced, and the inferior ear canal skin flap covers the facial ridge and the inferior part of the cavity (Fig. **574**). The anterior skin flap covers the mastoid tegmen and tegmen tympani, and epithelialization can take place. The lateral skin flap is sutured as a Körner's flap to the posterior edge of the cavity. Reconstruction in Bondy's operation is easy, especially if all the meatal skin is preserved and the cavity is not too large, as is the case with a sclerotic mastoid process or diminished pneumatization. After the medial part of the cavity has been packed, a meatoplasty is performed.

If the hearing is good and the matrix covers both the lateral aspects of the incus body and malleus head, then the functional results can be excellent.

Bondy's operation is not without drawbacks. Incomplete mastoid cell removal often leads to chronic discharge from the mastoid cavity. Residual cholesteatoma matrix can continue eroding the bone and stimulate the formation of granulation tissue. In addition, incomplete mastoid tip cell removal, with a resulting lack of ventilation, can cause infection and granulation. Bondy's operation is therefore no longer the preferred procedure in open cavity techniques in many centers.

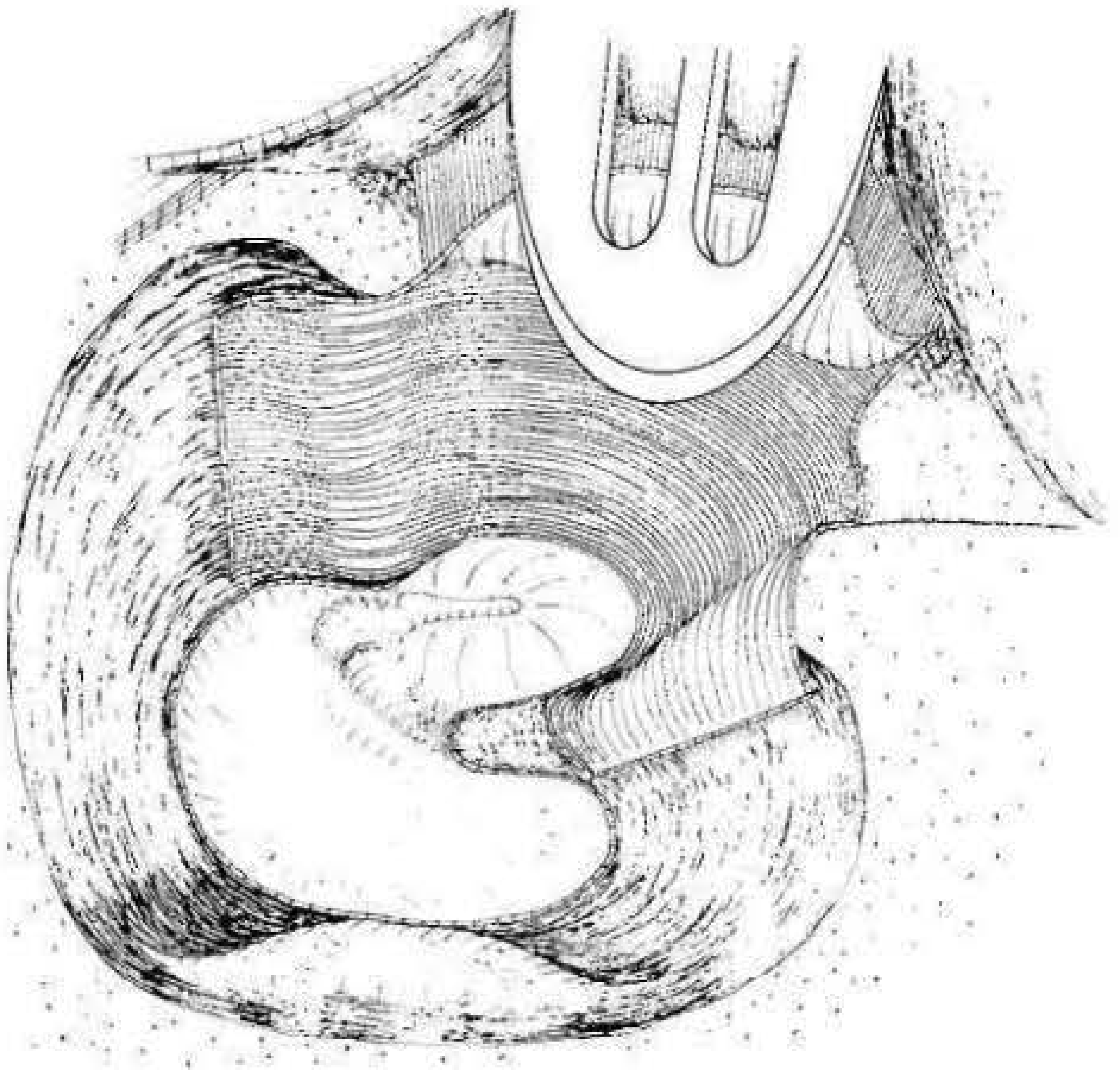


Fig. **574** **Reconstruction of the open Bondy cavity.** The superior meatal skin is placed over the mastoid tegmen. The medial walls of the attic and antrum wail, including the ossicles, are covered with a solid matrix. The facial ridge is covered with an inferior ear canal skin flap, extending into the inferior cavity. The posterior part of the cavity will be covered with a laterally-based ear canal skin flap (a Körner's flap) fixed to the posterior edge of the cavity

In small attic cholesteatomas and attic cholesteatomas with extensive resorption of the lateral attic wall, the ear canal can be removed before the cholesteatoma sac is opened (Fig. **10**).

Preservation of the Cholesteatoma Matrix

As mentioned previously, the definition of Bondy's operation, in addition to preserving the cholesteatoma matrix, includes the fact that the tympanic cavity is not entered. Bondy's operation is therefore limited to selected cases with less extensive cholesteatoma and without major resorption of the incus or the malleus head.

In cases of attic cholesteatoma with *extension into the tympanic cavity,* either laterally or medially, or simply by resorption of the incus body and malleus head, the cholesteatoma has to be removed from the tympanic cavity. In a conservative radical operation with removal of the bony bridge or an atticoantrotomy, the cholesteatoma can be marsupialized and the matrix left in place in the attic alone (Figs. **12, 13**). Some of the matrix is elevated, and the tympanic cavity is closed with an underlay fascial graft (Fig. **14**).

The Sanna Modification

To stabilize the marsupialization techniques on a long-term basis, in canal wall–down mastoidectomy or Bondy's operation, Sanna et al. (1994) introduced an improvement of the marsupialization technique, elevating the cholesteatoma matrix from the incus and including the posterosuperior part of the drum (Fig. **575**), exposing the incudostapedial joint. A small piece of cartilage is placed under the short process of the incus, preventing later retraction. Another thin cartilage plate is placed on the long process of the incus and under the malleus handle, preventing posterosuperior retraction (Fig. **576**). Both pieces of cartilage are covered with a specially cut fascia graft, placed under the drum (Fig. **577**) which is re-placed in the proper position, so are the matrix and the skin flaps (Fig. **578**). Sanna also elevated the matrix, inspecting the perilabyrinthine cells to avoid ingrowth of the matrix into the cells. The indications for marsupialization and Bondy's operation are wider with this modification.

The result of Sanna's modification of the canal wall–down mastoidectomy technique is the same as that of Bondy's operation (Landolfi et al. 1993). The marsupialization technique can sometimes be used to great advantage. In the majority of cases, however, a conservative radical operation with removal of the bridge is performed, including *total removal of the cholesteatoma,* leaving no matrix.

Baron (1949, 1967), a great advocate of preservation of the matrix in cholesteatoma surgery, suggested a number of rules for the preservation or removal of the matrix (Table **7**).

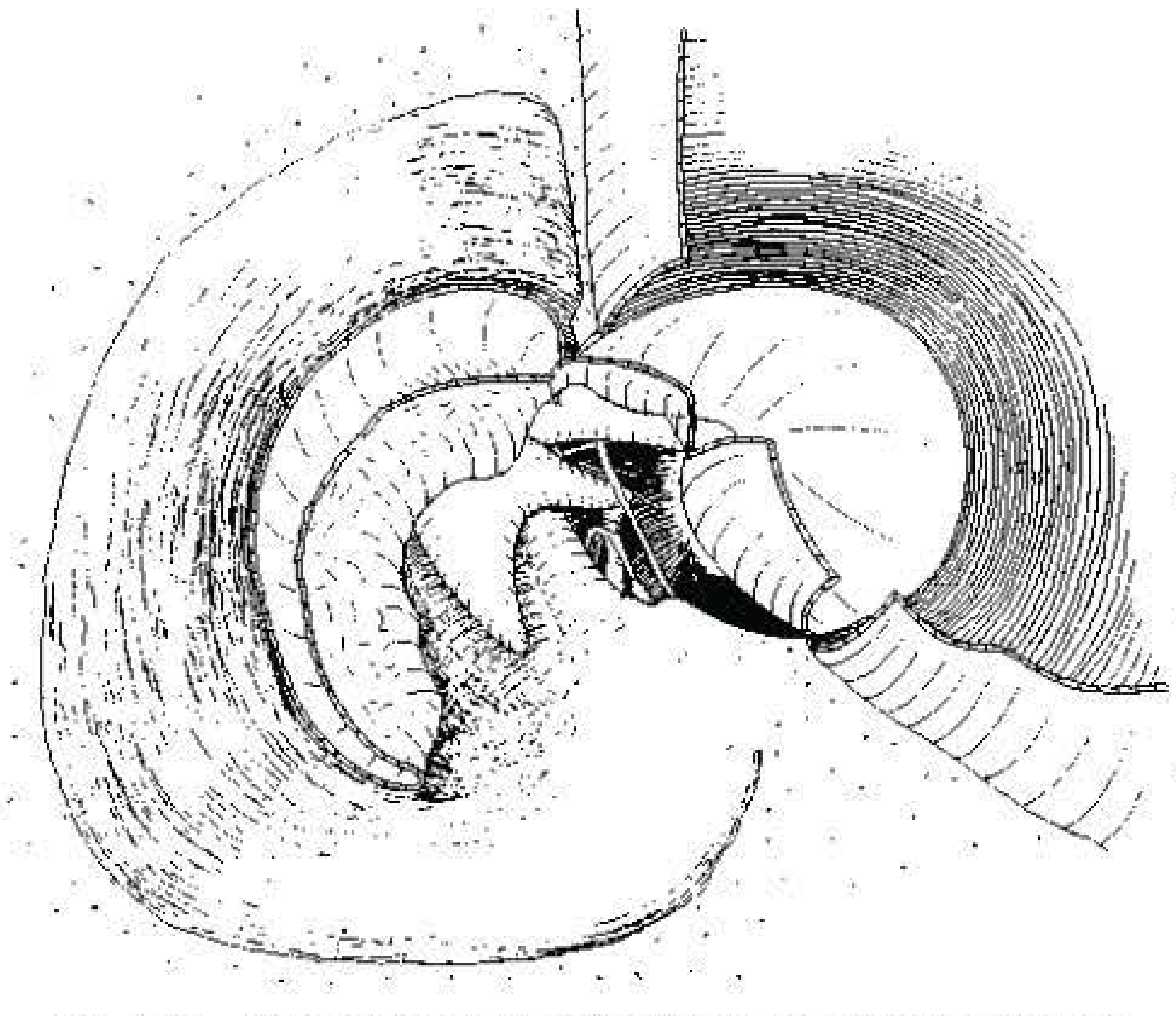


Fig. **575** **The Sanna modification of the marsupialization technique and Bondy's operation.** The matrix covering the incus is removed and the posterosuperior part of the drum is elevated, exposing the intact incudostapedial joint

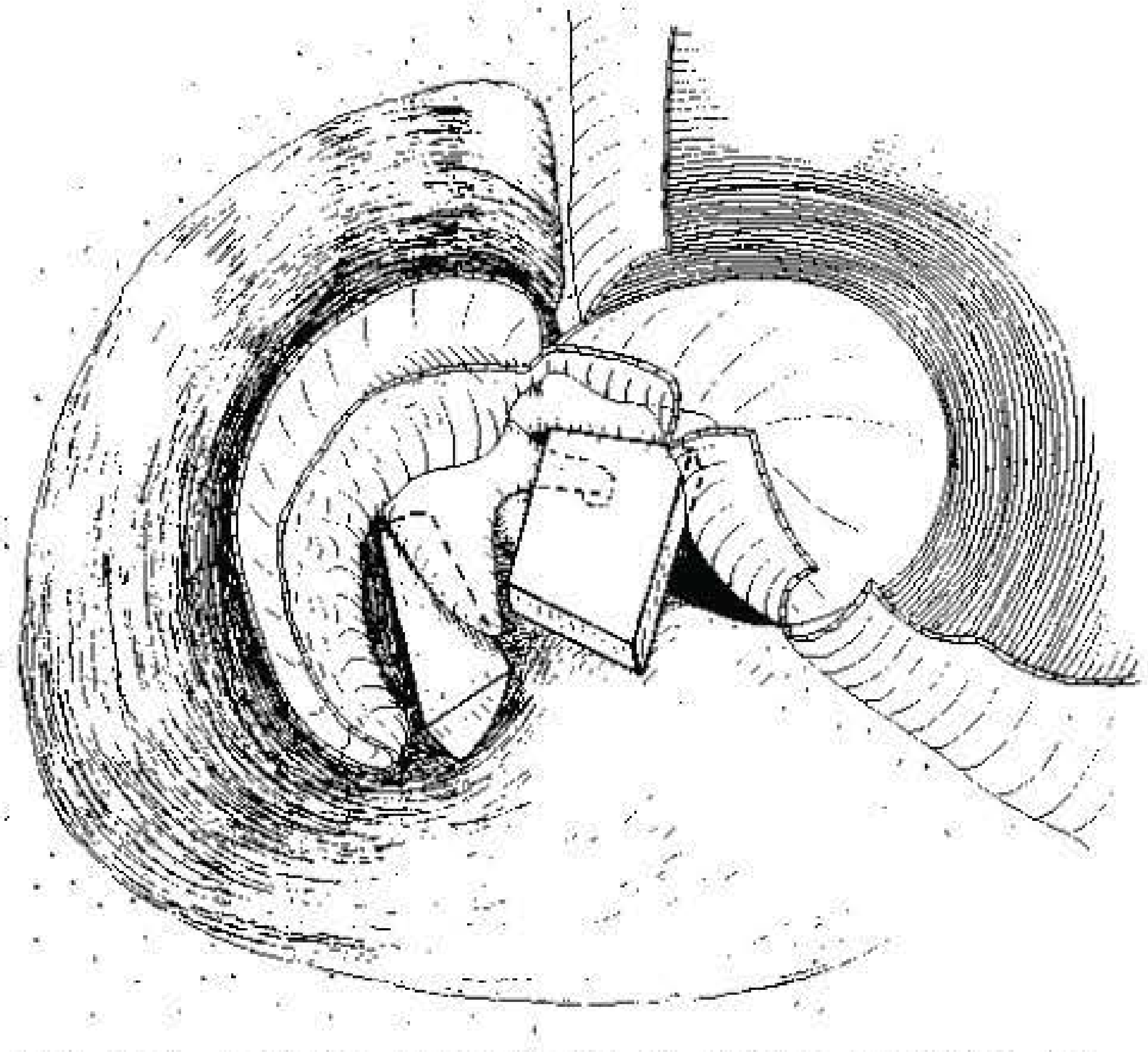


Fig. **576** A piece of cartilage is placed between the short process of the incus and the medial attic wall. Another rectangular piece is placed on the long process of the incus and under the malleus handle

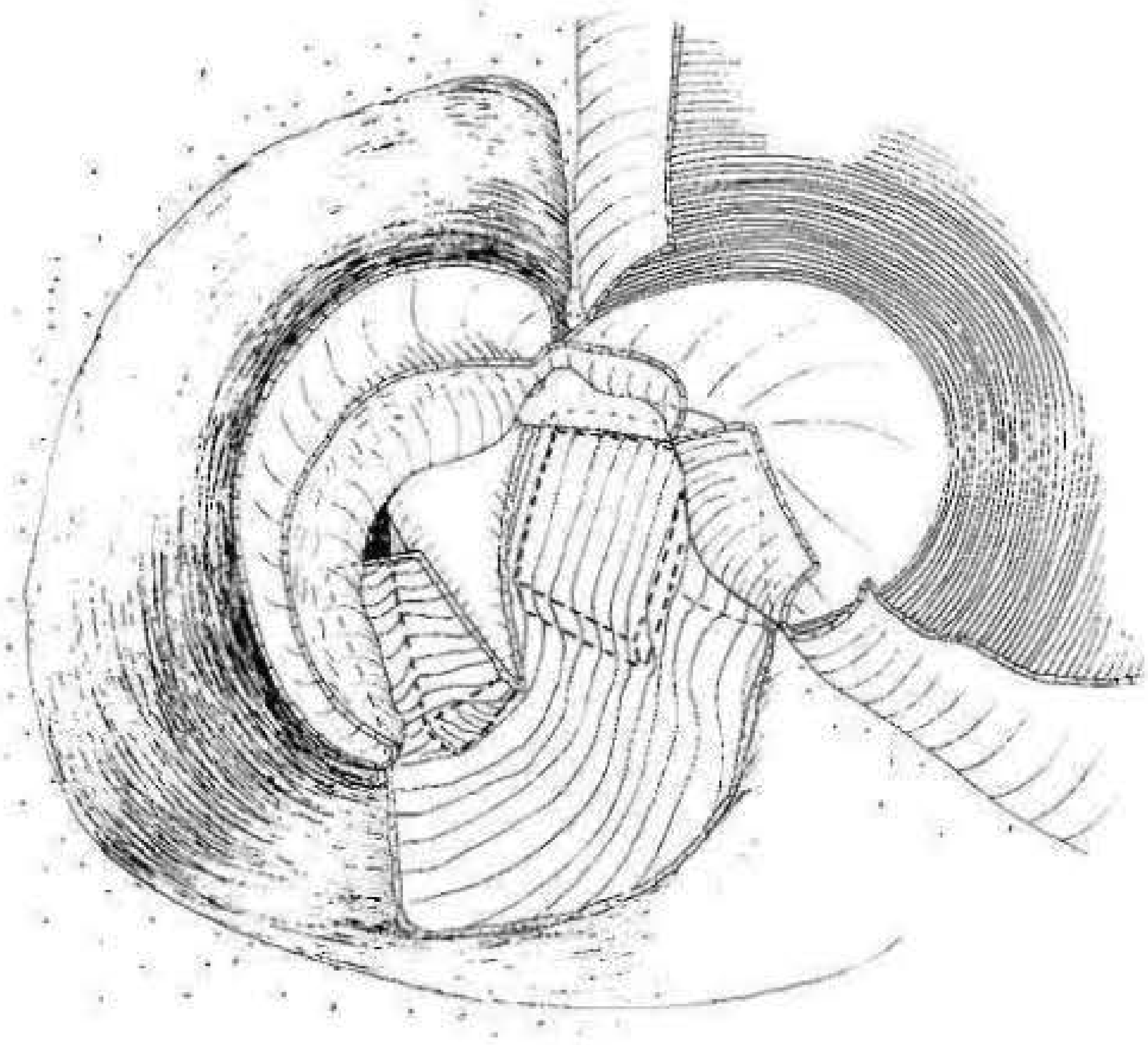


Fig. **577** A specially cut piece of fascia covers the cartilage, incus, and posterosuperior part of the drum as an underlay graft

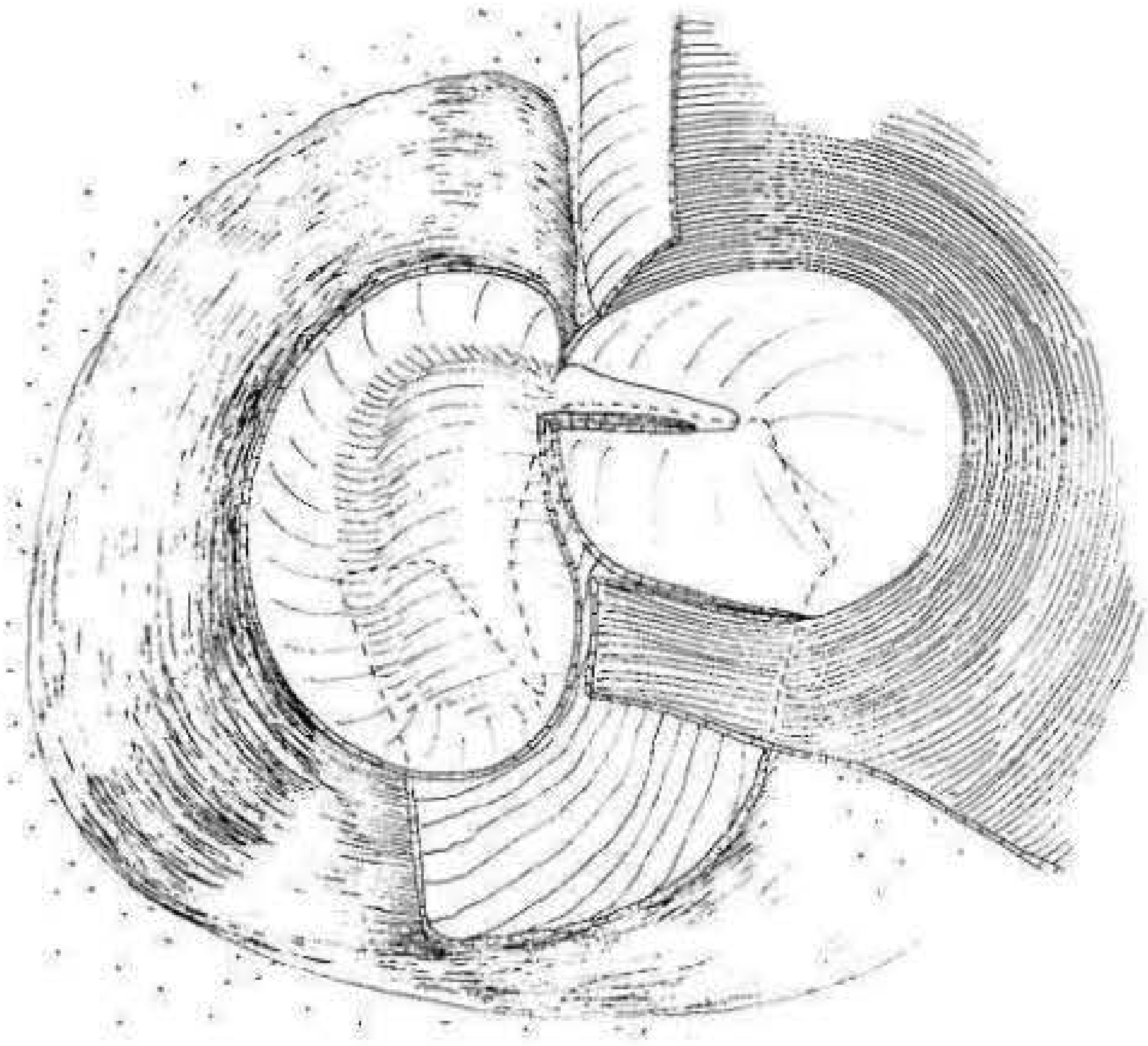


Fig. **578** The matrix and the drum are replaced in their original position

Table **7** Baron's rules for preservation or removal of cholesteatoma matrix (Baron 1949, 1967)

Preserving the matrix

1 Cases with externalized squamous epithelium that serves as a source of complete epithelialization for the mastoid cavity, resulting in a dry ear.
2 For maintenance or improvement of hearing, especially in the ear with better hearing or in the only hearing ear.
3 In a sclerotic mastoid.
4 In a labyrinthine fistula.
5 In cases with exposed dura, sinus, or facial nerve.

Removing the matrix

1 In a well-pneumatized mastoid.
2 With perilabyrinthine invaginations and fingerlike protrusions into the air cells.
3 In revision operations.
4 With retrofacial or petrous tip extensions.
5 With invagination into bone in any area.
6 For cases with hearing loss greater that 45 dB, the matrix should be removed and reconstruction of a conducting mechanism attempted.
7 Where there is suppuration between matrix and the bone.
8 With granulation tissue between islands of matrix.
9 In cases of labyrinthitis, petrositis, meningitis, subarachnoid abscess, epidural abscess, and lateral sinus thrombosis.

Canal Wall–Down Mastoidectomy with Removal of the Bridge

A transcortical canal wall–down mastoidectomy is initially a cortical mastoidectomy, described in Chapter 4. Only the special techniques involving removal of the bridge, polishing of the anterior and superior walls of the cavity including its transition into the anterior ear canal wall, as well as removal of the facial ridge and the posterior buttress, will be described here.

After removal of the lateral mastoid air cells and Körner's septum, the cavity is polished, and the large cells are removed, ensuring that no cholesteatoma and no granulation cholesteatoma with infection remains. The ear canal skin is elevated from the bony wall, preserving both a large superior and inferior skin flap.

Removal of the Bony Ear Canal Wall

The bony ear canal can be removed at any stage of a cortical mastoidectomy, but usually the antrum is entered and Körner's septum is removed before the ear canal is taken down.

The removal of the ear canal can be performed using a rongeur. The use of a rongeur has the advantage that pieces of the ear canal can be used as obliterating material, or for reconstruction of the bony ear canal wall, or as an ossiculoplasty graft. Before removal of the ear canal wall, it is wise to drill it thin and clean the cavity lateral to Körner's septum, polish the walls and sinodural angle, and exenterate the cells in the mastoid tip if there are any (Fig. **579**). By following the air cells down to the mastoid tip before removal of the bony ear canal wall, the surgeon is able to judge how much of the canal has to be removed in relation to the facial ridge in order to achieve a safe cavity. In cases with a small air cell system, the lateral part of the ear canal is removed with a rongeur (Fig. **580**) or drilled away using a cutting burr (Fig. **581**) as far as the bridge, lateral to the ossicles. Using a rongeur or a diamond burr, the bridge is then drilled away (Fig. **582**), and the drilling continues anteriorly in order to remove the remaining part of the bridge and smooth the anterosuperior part of the cavity.

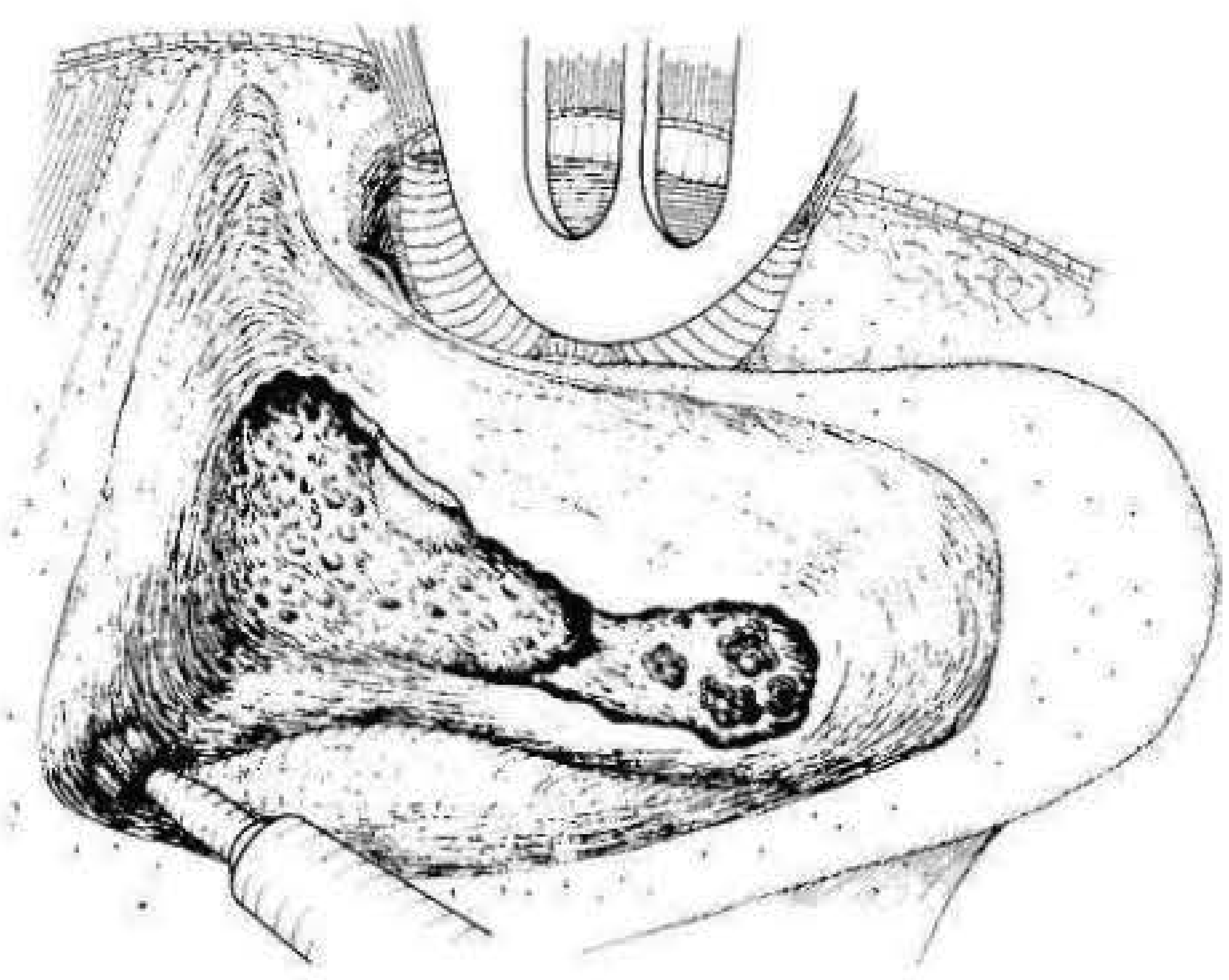


Fig. **579** **Cortical mastoidectomy in a case with extension of the cells into the mastoid tip.** The sinodural angle has been cleaned. The mastoid tegmen and the sigmoid sinus plate, as well as the posterior fossa dural plate, have been smoothed. The anterior attic will be opened after removal of the bony ear canal wall

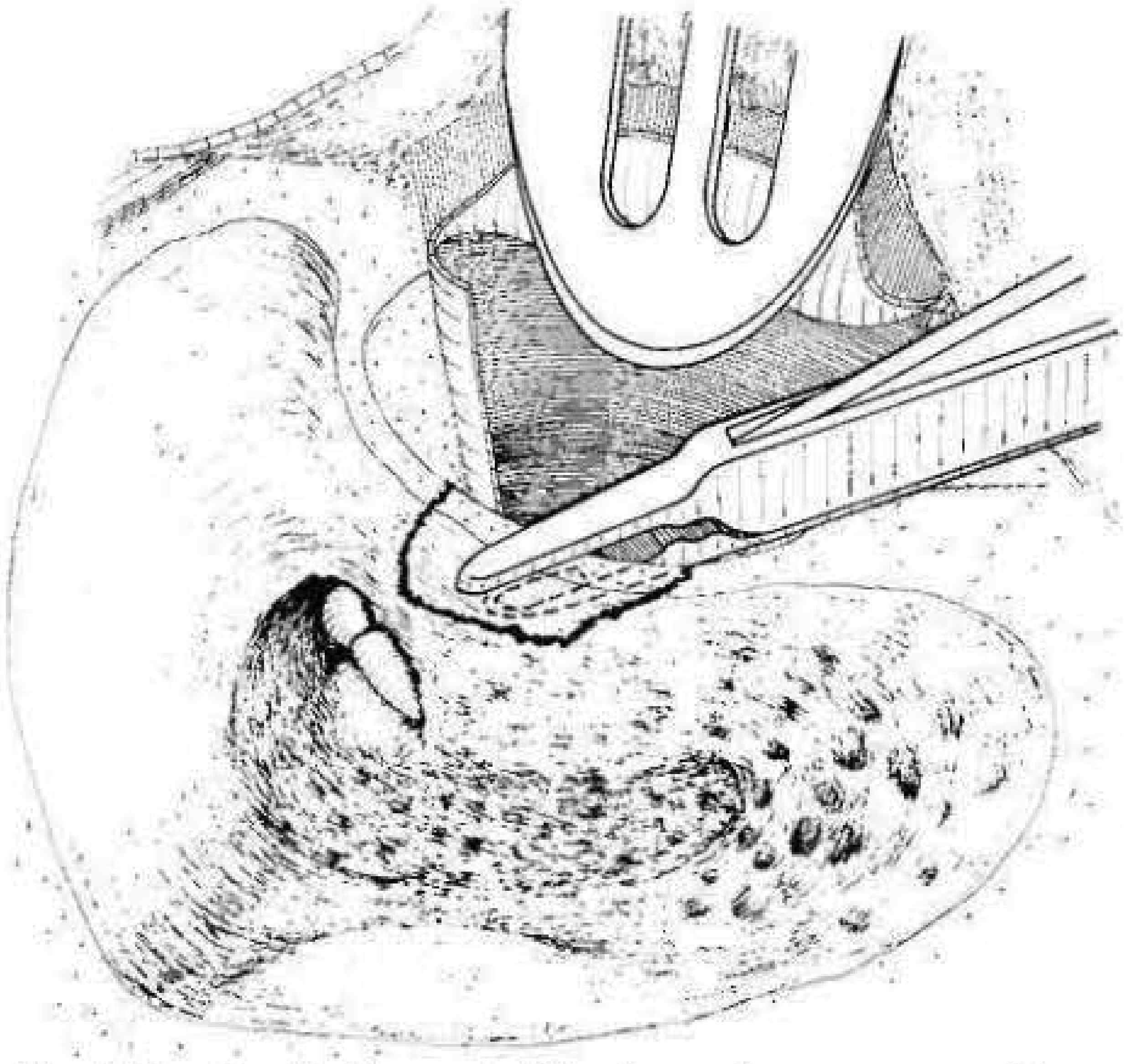


Fig. **580** **Cortical mastoidectomy in a case with a small-cell system** just before removal of the bony ear canal wall with a rongeur

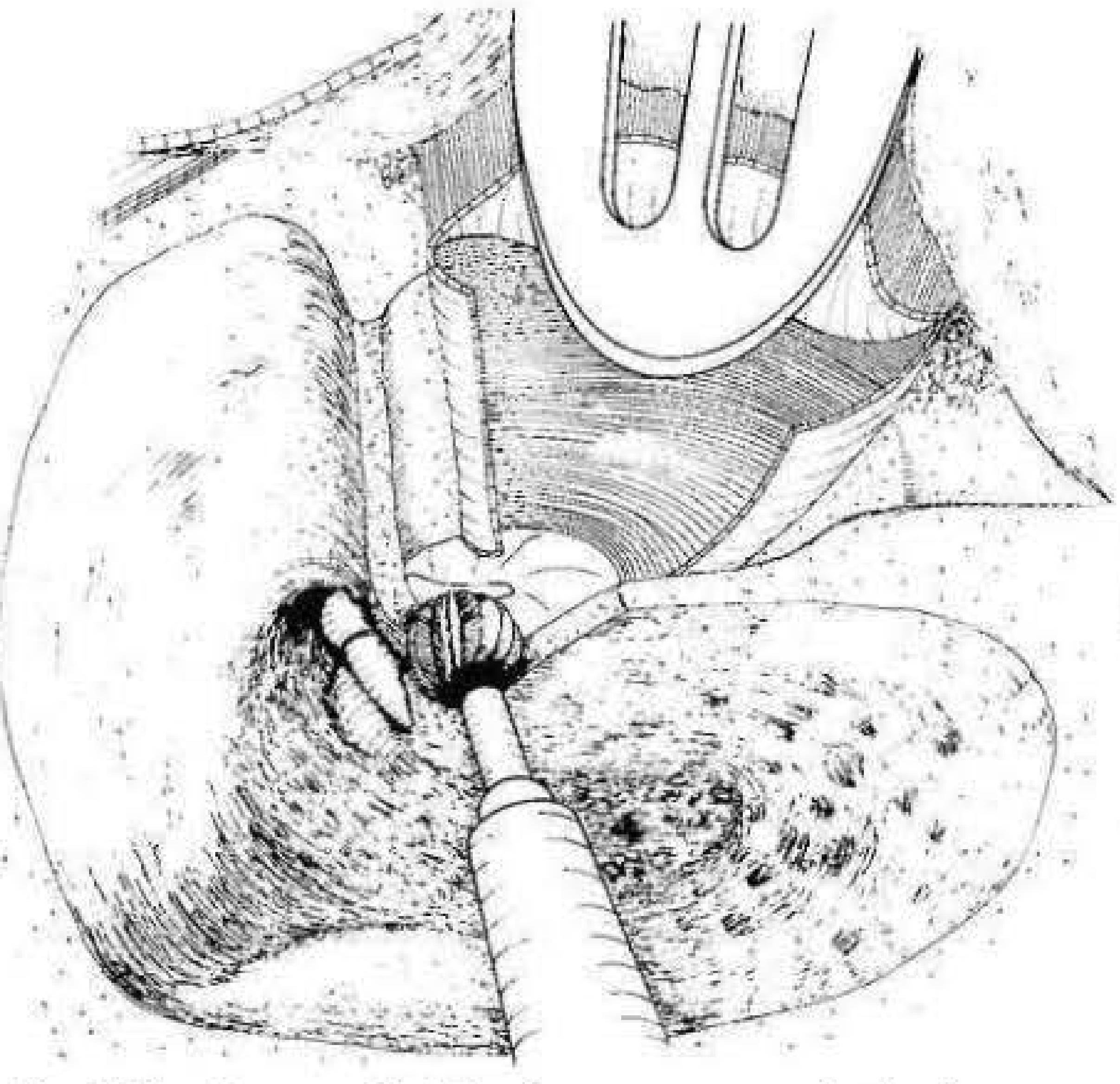


Fig. **581** **Removal of the bony ear canal.** The bony ear canal is drilled away with a cutting drill, preserving the bridge covering the ossicles

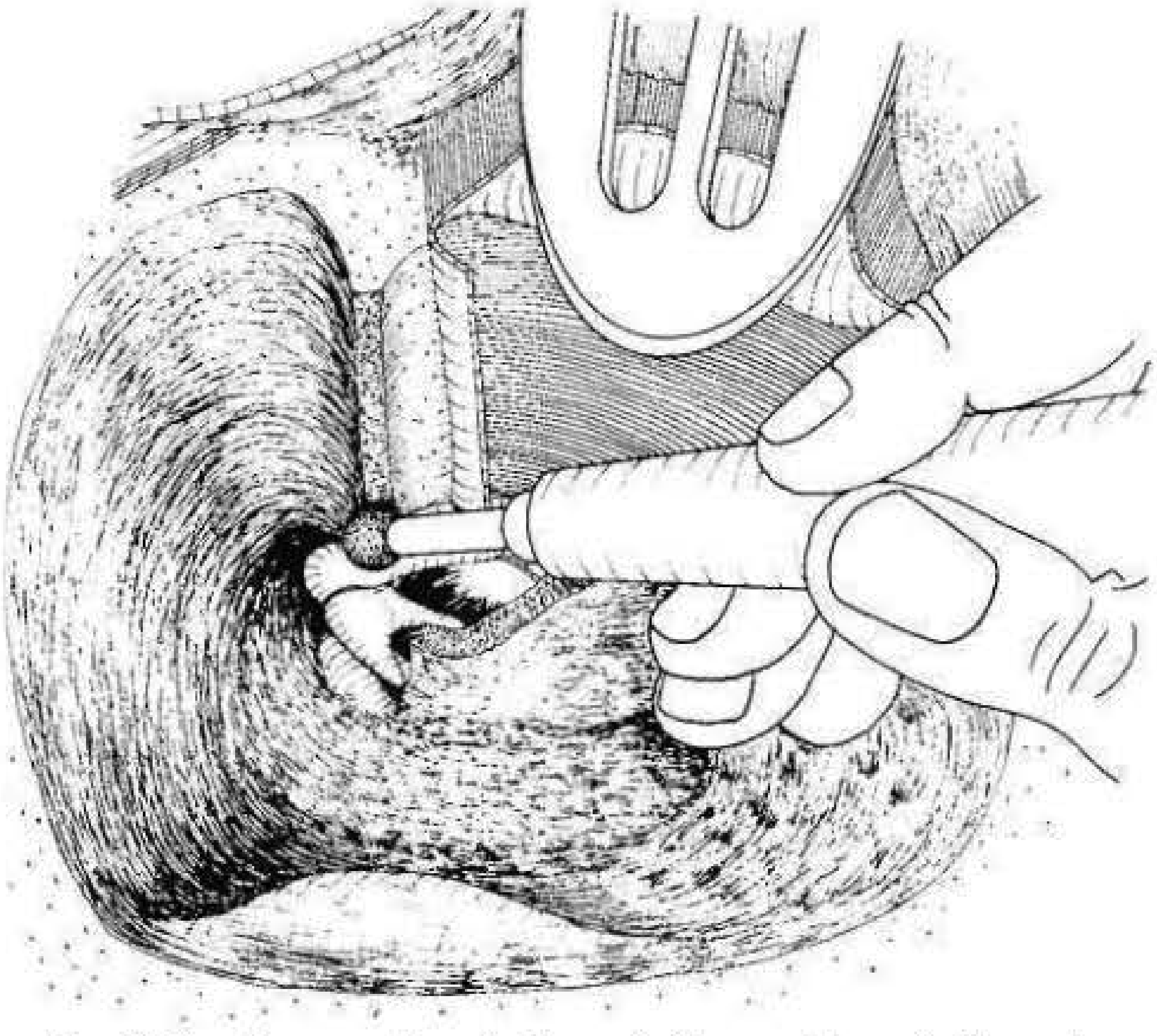


Fig. **582** **Removal of the bridge.** The bridge is removed, and the anterior buttress is drilled away using a diamond burr, initiating smoothing of the anterior cavity wall

Smoothing the Superior and Anterior Cavity Walls

When using the canal wall–down technique with removal of the bridge, it is very important for there to be no overhangs of the mastoid tegmen and no remnants of bone left at the origin of the bony ear canal wall. The anterior ear canal wall should continue directly and smoothly into the anterior and superior walls of the cavity. This drilling can start at the anterior buttress, just lateral to the malleus head. The bone removal is continued laterally, using either a cutting burr or a diamond burr, depending on the amount of bone to be drilled away. If the zygomatic region is smoothed and no cells are present, the anterior part of the cavity will be small, but if there are large zygomatic cells, they should be exenterated, and then in addition quite a lot of the anterior ear canal wall needs to be removed. This means that the extent of the anterior bone removal depends upon the degree of pneumatization and the presence of zygomatic cells. Finally, the transition of the anterior meatal wall and zygomatic root to the anterior cavity wall and further to the superior cavity wall is drilled, continuing posteriorly into the sinodural angle and along the sigmoid sinus toward the mastoid tip, with all the overhangs and irregularities of the bone being removed (Fig. **583**).

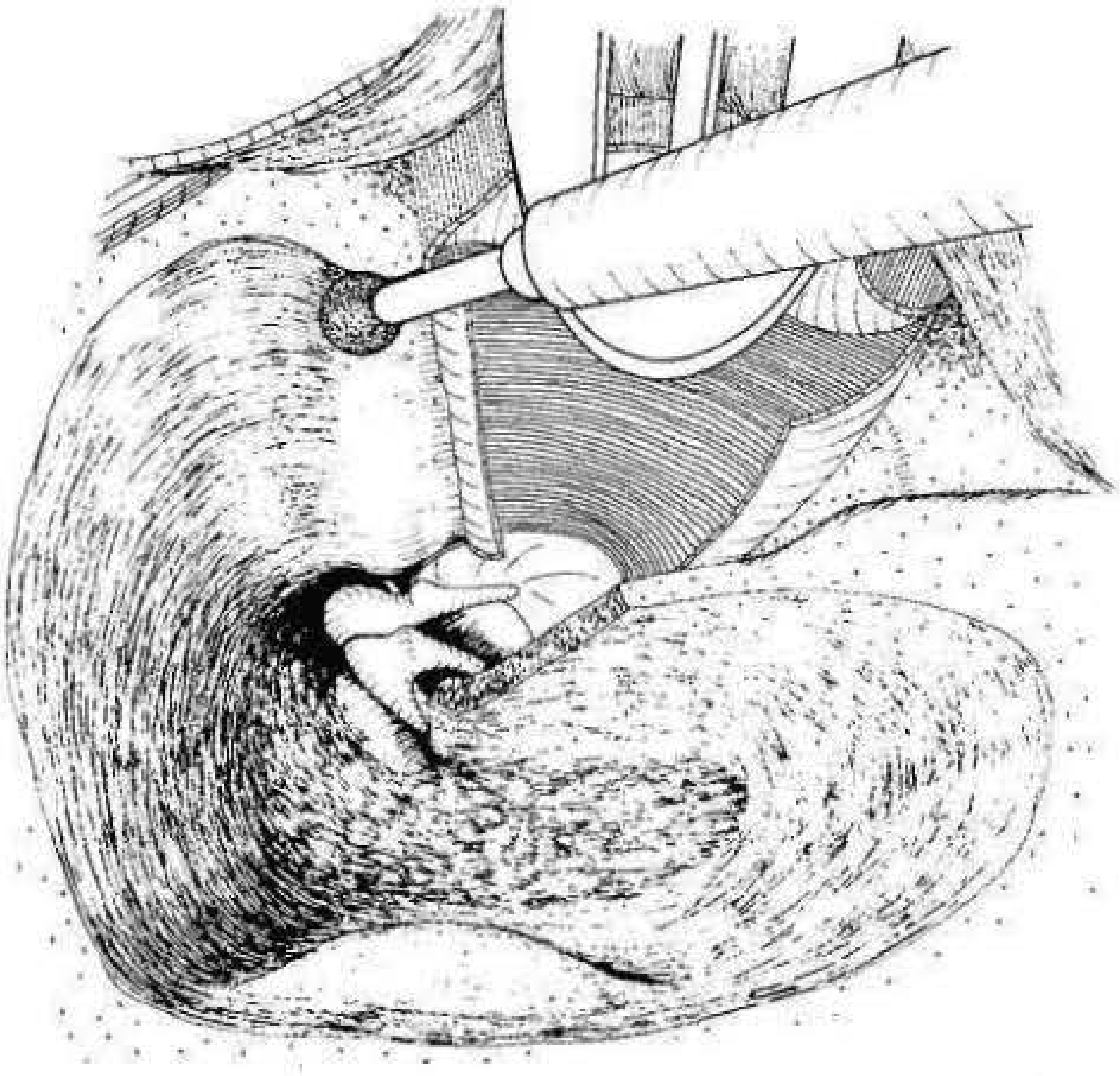


Fig. **583** **Smoothing of the anterior cavity wall.** After removal of the anterior buttress, the remaining superior part of the ear canal wall is removed and the transition from the ear canal to the cavity is smoothed, eliminating the border between the anterior meatal wall and the anterior and superior walls of the cavity

Removal of the Facial Ridge

As mentioned above, the posterior part of the ear canal is usually removed, and the facial ridge is lowered, especially in ears in which the bony bridge has been removed and an open cavity is desired, or an obliteration is to be performed with tissues that may later atrophy or disappear, resulting in a cavity behind a high facial ridge that cannot be inspected or cleaned. The lowering of the facial ridge is therefore an important procedure, and should be related to the expected size of the cavity and the possibility of an eventual obliteration. The facial ridge can be shaped in various ways, depending on a) the pathology; b) the remaining ossicular chain; c) the desired height of the attic; d) the depth of the cavity; and e) the degree of pneumatization.

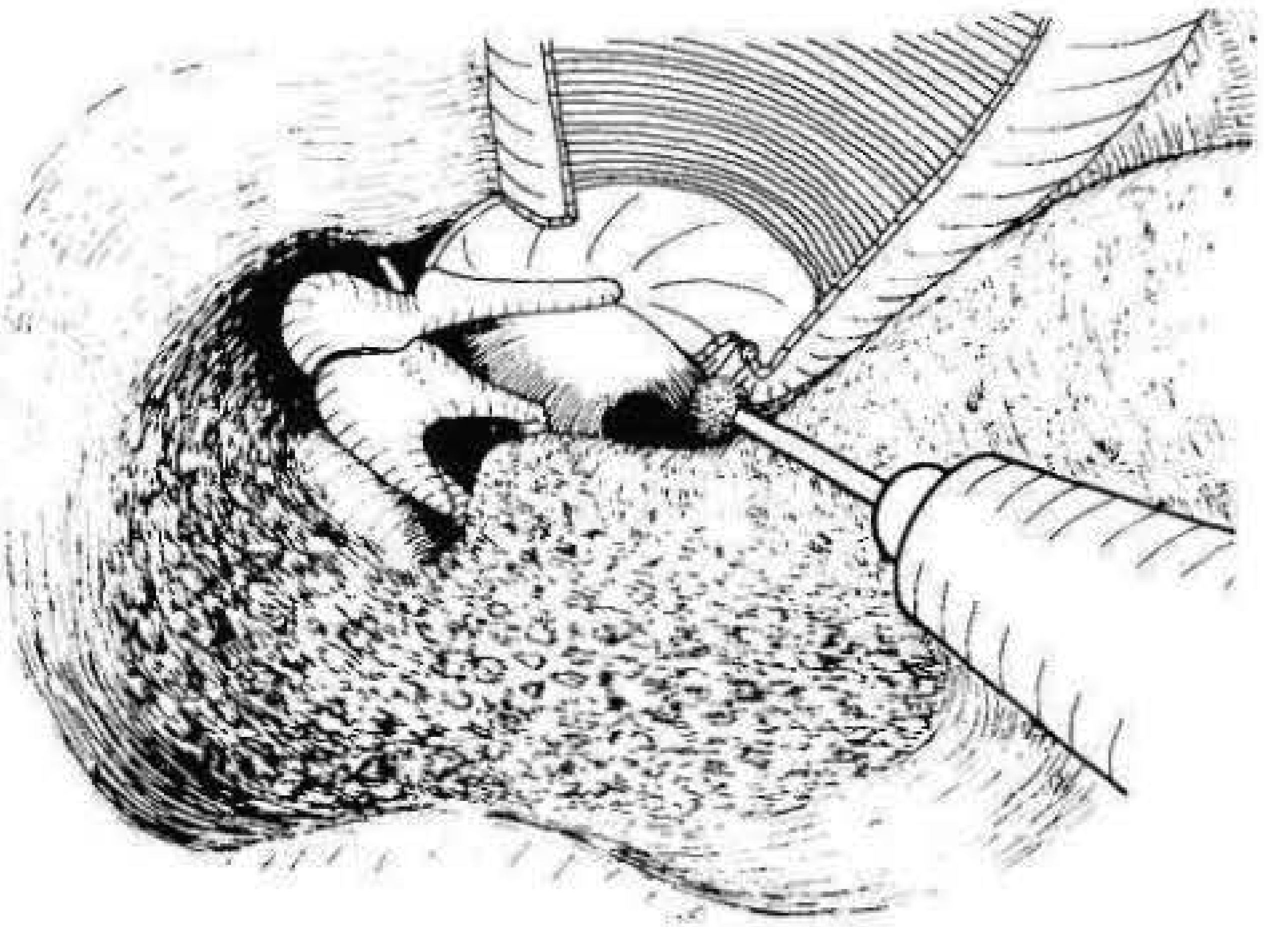


Fig. **584** **Lowering the facial ridge.** The facial ridge has been lowered and reduced, especially on the tympanic side, in a case of sinus cholesteatoma with an intact ossicular chain. The posterior buttress has not been removed, and the ridge is still relatively high, providing good support for reconstruction of the drum and ventilation of the attic

In sinus cholesteatoma with pathology within the tympanic sinuses, the posterosuperior part of the bony annulus is removed in order to visualize the sinuses. Subsequently, the remaining facial ridge is lowered, especially on the meatal side (Fig. **584**), but the posterior buttress can sometimes be preserved in order to maintain the height of the tympanic cavity. In such cases, if the cholesteatoma is removed and the ossicular chain preserved, the attic can be covered by fascia and re-pneumatized, even if the remaining cavity is left open or obliterated (Fig. **585**). If the pathology requires the posterior buttress to be removed, exposing the genu of the facial nerve and the stapes (Fig. **586**), the reconstruction can be similar, with ventilation of the attic and an intact ossicular chain (Fig. **585**).

In order to remove pathology from the tympanic sinuses, the posterior buttress is completely removed down to the facial nerve, and the resulting facial ridge is very low (Fig. **587**). If the ossicular chain is intact, which is an extremely rare situation, safe reconstruction is possible whilst still trying to ventilate the attic (Fig. **585**).

In sinus cholesteatoma and tensa retraction cholesteatoma, the incus is usually missing, and removal of the posterior buttress and maximal lowering of the facial ridge (Fig. **588**) are often necessary. By placing a bony graft onto the stapes and leaving the malleus head in place, a reasonable height for the tympanic cavity can be achieved (Fig. **589**). If the pathology requires the malleus head to be removed, then it will be necessary to drill away more of the anterior attic wall (Fig. **590**) in order to avoid an overhang of bone and prevent retraction into the epitympanic sinus. Reconstruction by interposition between the malleus handle and the head of the stapes and covering of the medial attic wall will result in a stable situation with an open attic (Fig. **591**).

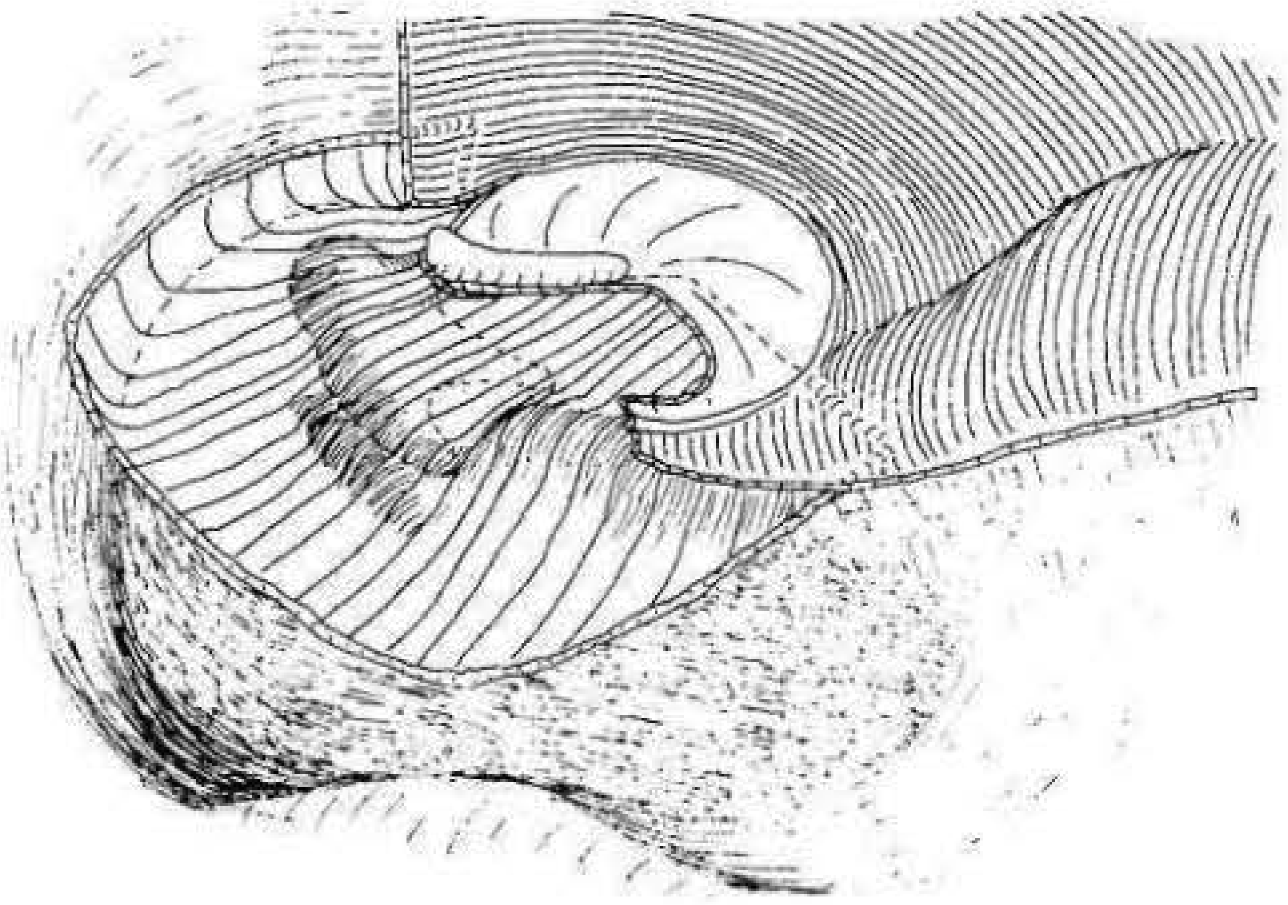


Fig. **585** **Reconstruction of the attic.** The fascia covers the perforation and the ossicular chain. It is supported by the facial ridge and superior attic wall

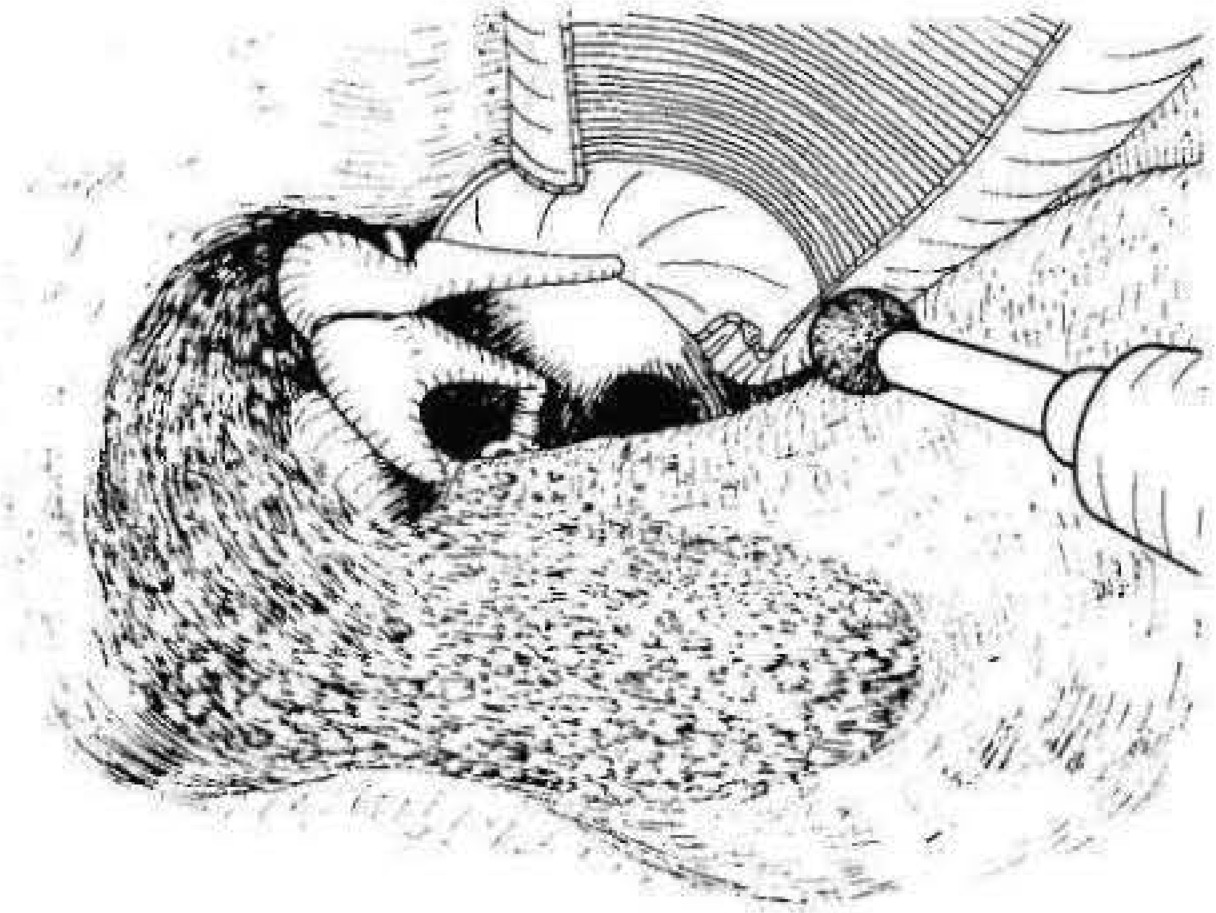


Fig. **586** Part of the posterior buttress has been removed and the facial ridge is exposing the stapes further. A reconstruction of the tympanic cavity with ventilation of the attic is possible, because the facial ridge is still relatively high and the ossicular chain is intact

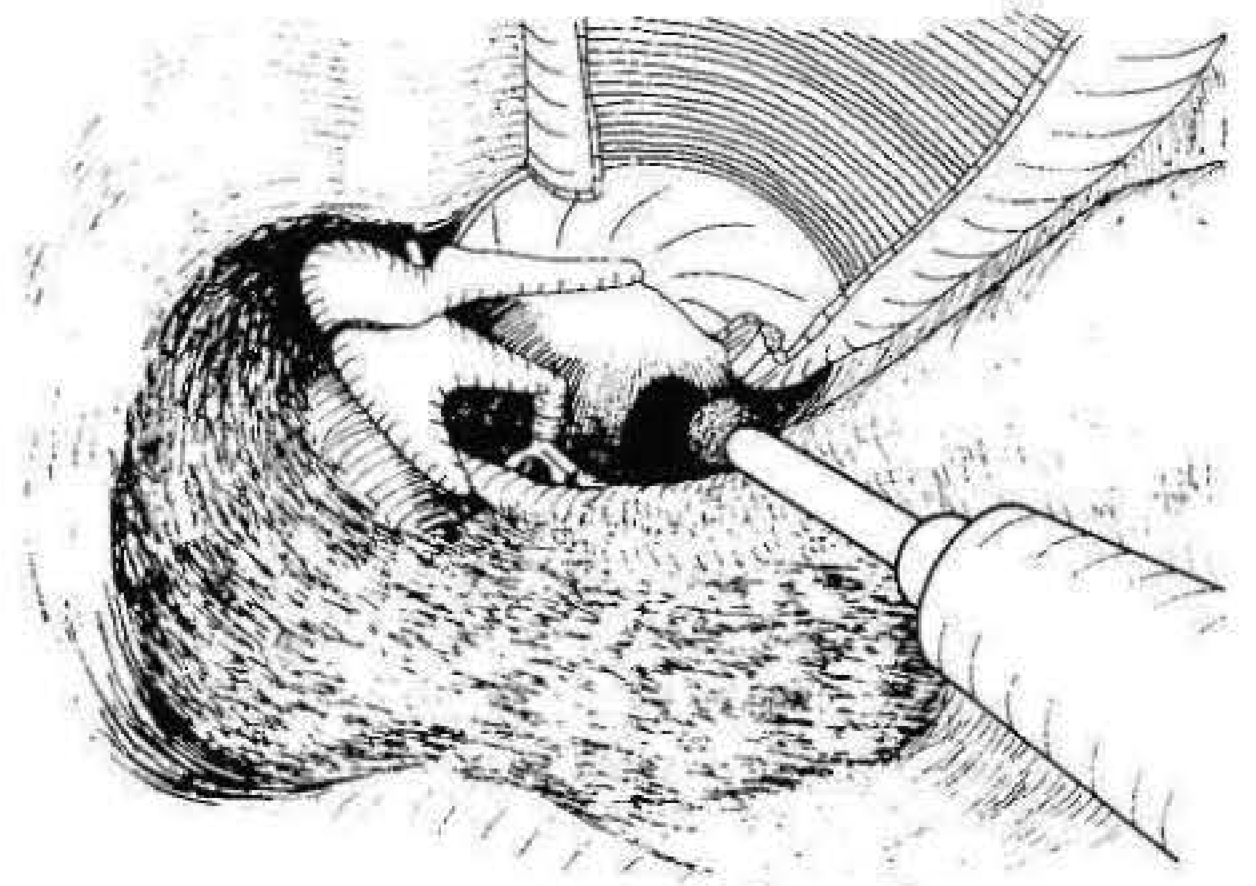


Fig. **587** In a case of sinus cholesteatoma, the facial ridge has been removed down to the facial nerve, skeletonizing the genu of the facial nerve, exposing the pyramidal eminence, and removing the lateral tympanic sinus. The ossicular chain is intact, and reventilation of the attic, maintaining a certain height in the tympanic cavity, is still possible

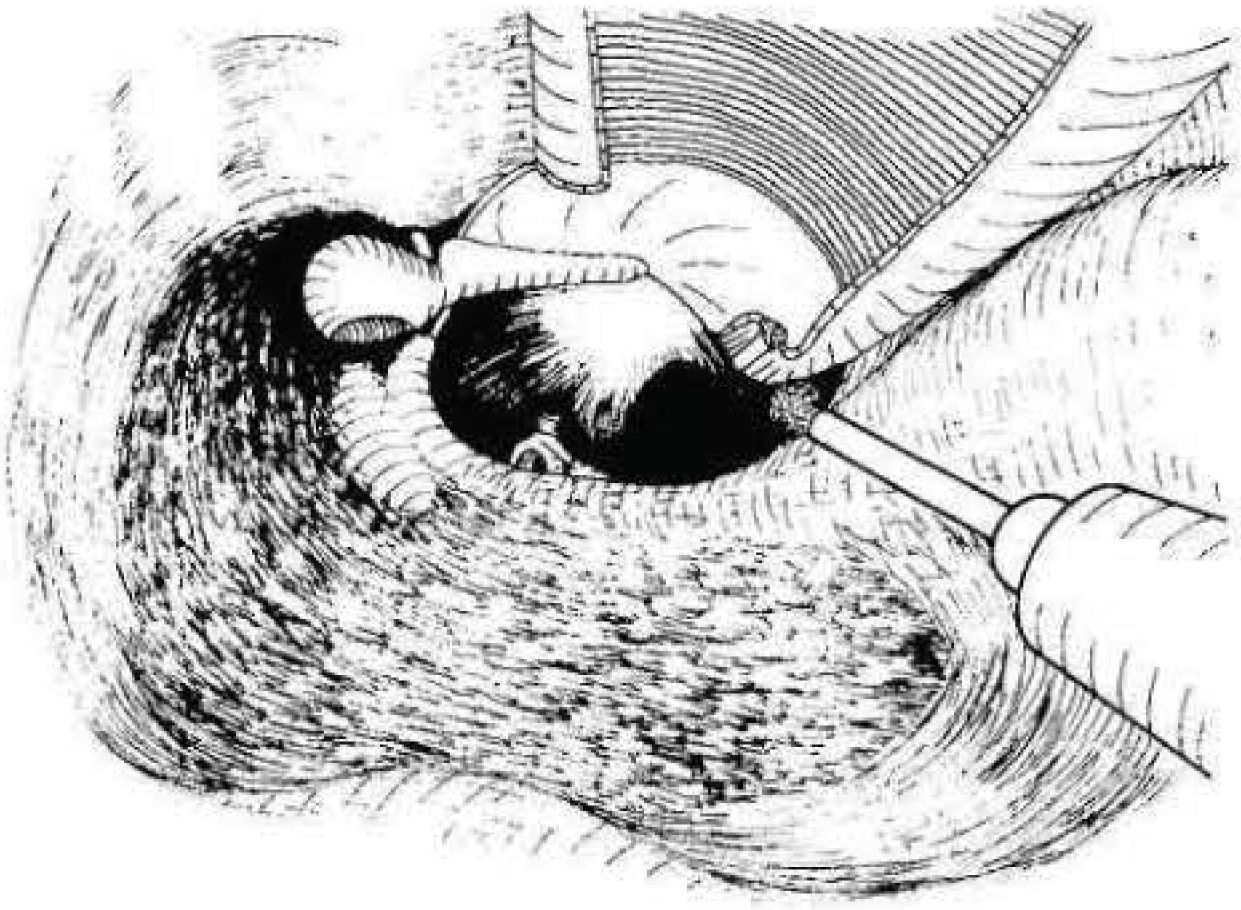


Fig. **588** **Considerable lowering of the facial ridge** down to the facial nerve, which is skeletonized. Lowering of the facial ridge is especially extensive on the tympanal side, exposing the tympanic sinus. The incus is missing, but the malleus head is present, allowing reconstruction of the tympanic cavity after ossiculoplasty, and ventilation of the anterior attic

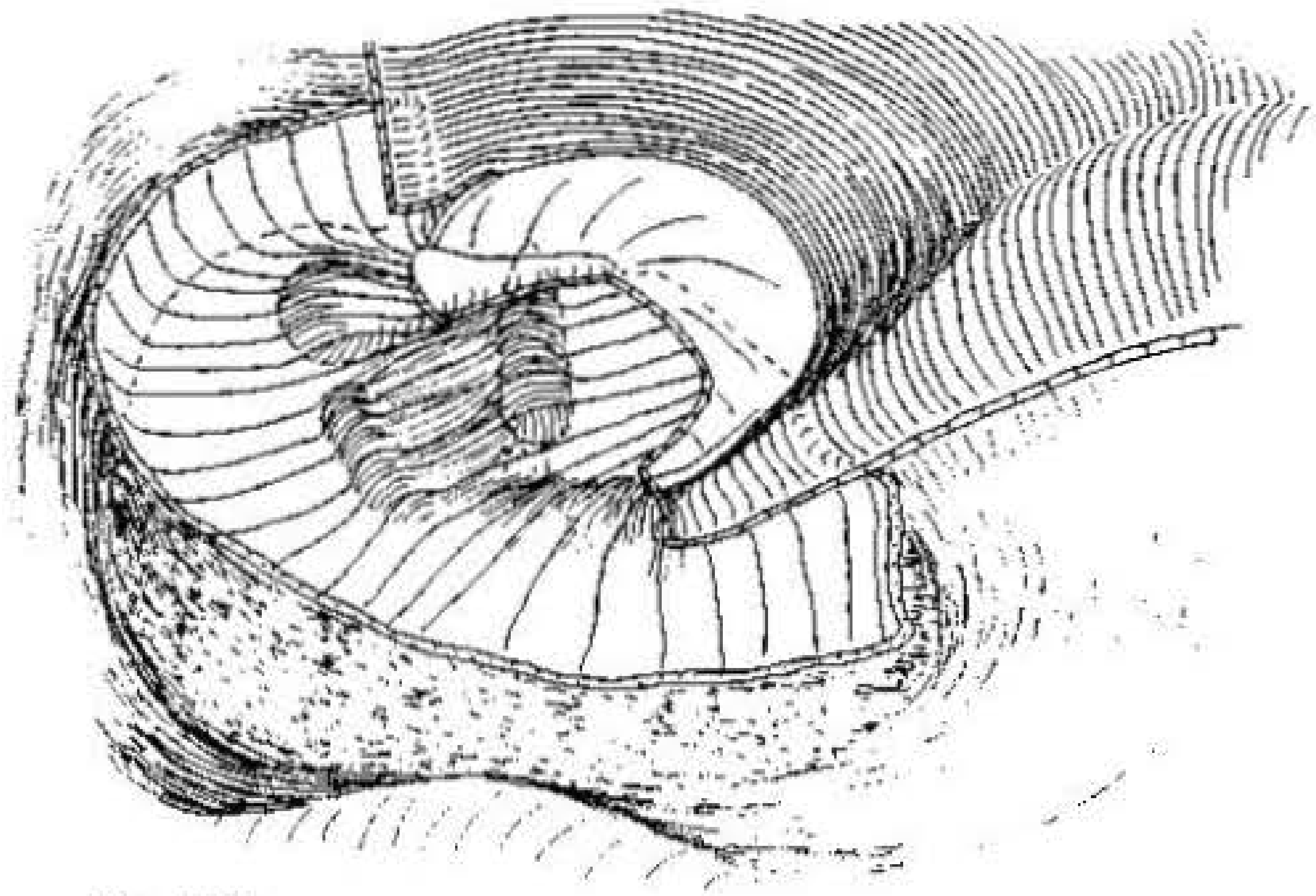


Fig. 589

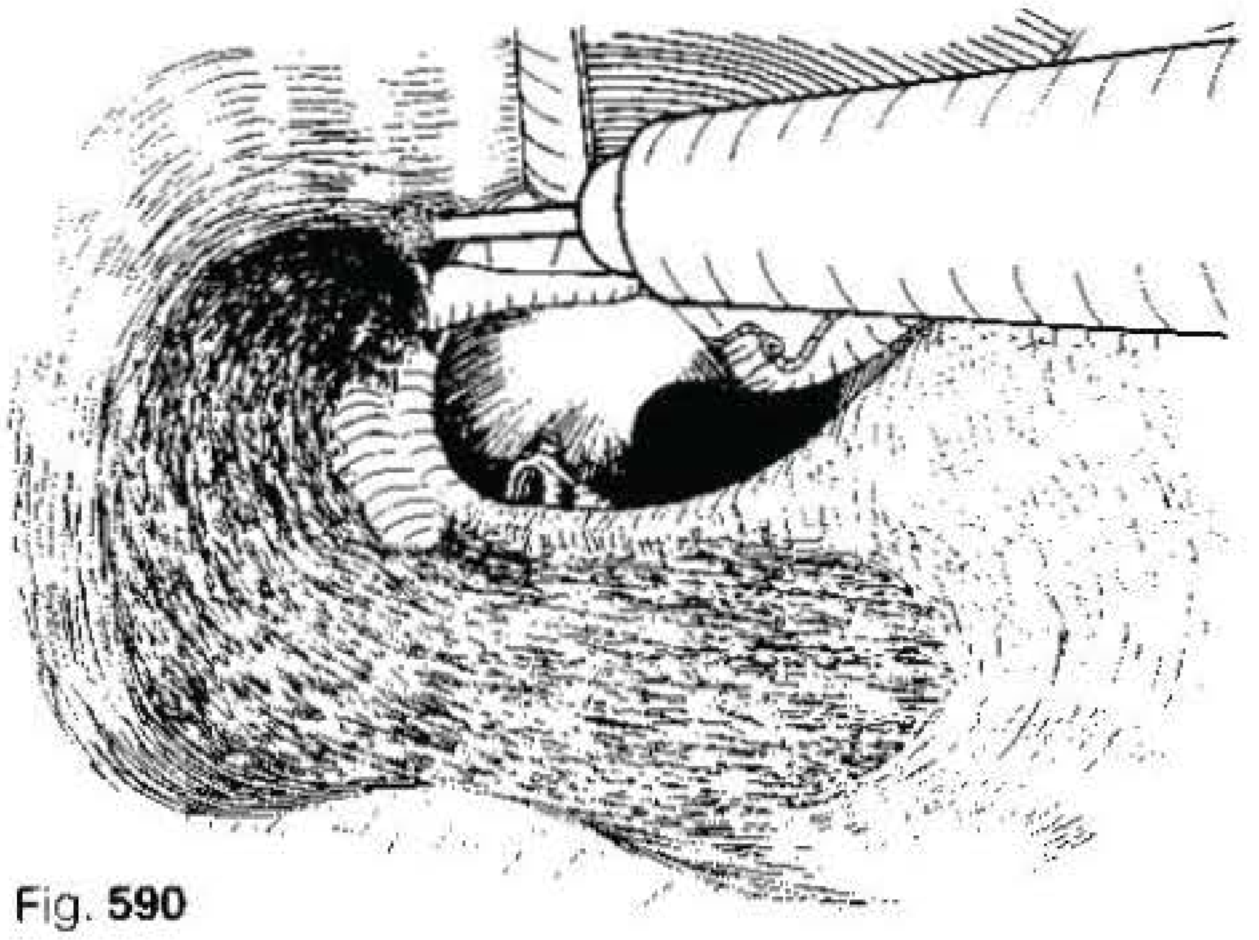


Fig. 590

Fig. **589** **Reconstruction.** A piece of autogenous bone is shaped and placed on the head of the stapes as an interposition graft. Fascia covers the head of the malleus and the bony graft, ventilating the anterior attic

Fig. **590** **Extensive lowering of the facial ridge and skeletonizing the genu of the facial nerve.** The malleus head has been removed, so that the anterior buttress has to be more extensively drilled away, preventing an overhang there and potential retraction into the epitympanic sinus. The tympanic cavity will be low and the attic will have an open cavity

Fig. **591** **Reconstruction.** Fascia covers the bony graft, the perforation, the medial wall of the attic, the facial nerve eminence, and the lateral semicircular canal

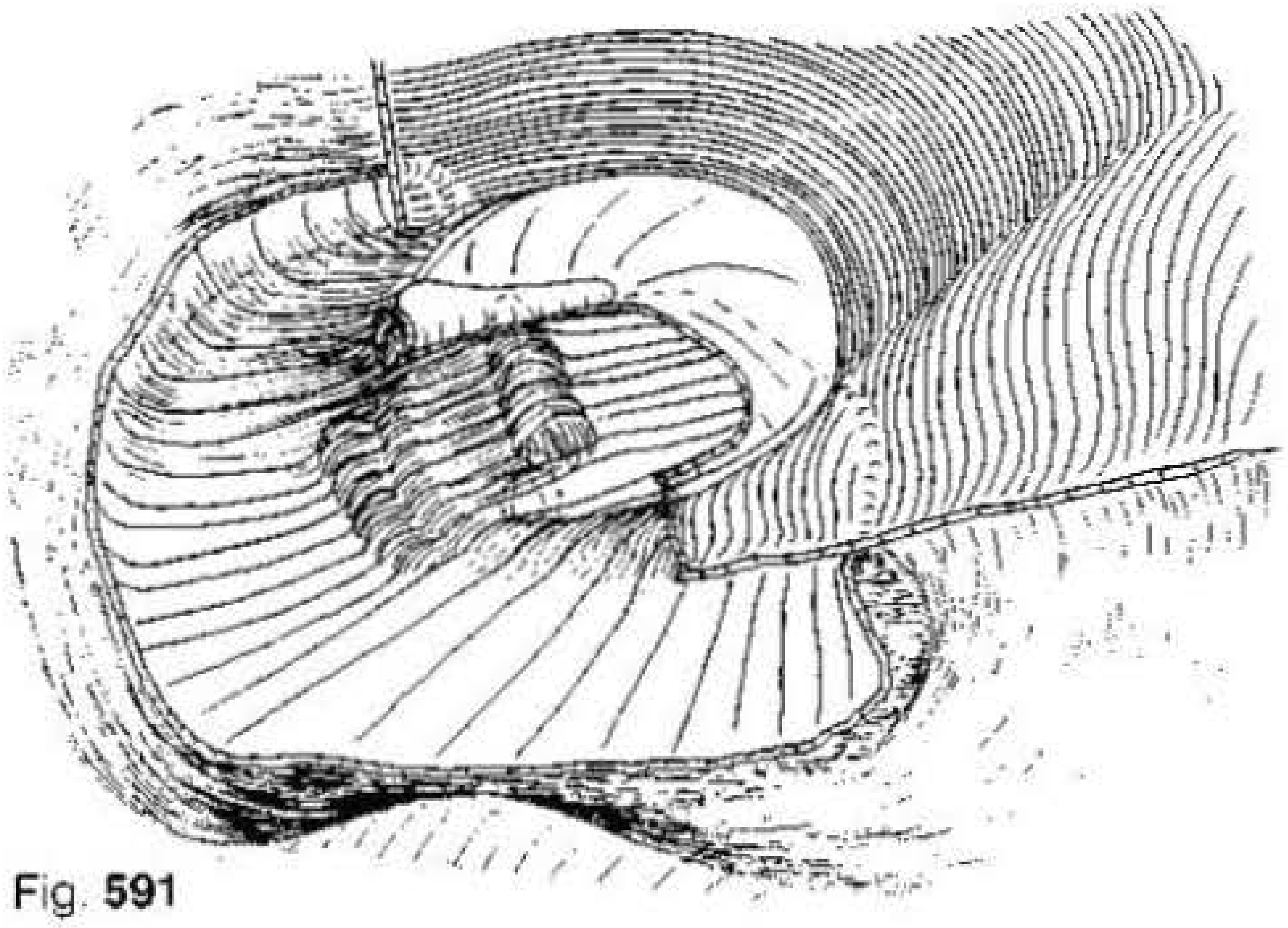


Fig. **591**

Partial Preservation of the Bridge

In sinus or tensa retraction cholesteatoma, instead of removal of the posterior buttress, an atticotympanotomy can be performed and part of the posterior bony bridge preserved, maintaining a better height of the tympanic cavity (Fig. **592** and **593**). At the same time part of the anterior bony bridge can be preserved, preventing retraction between the malleus and the anterior attic. In such cases the attic is ventilated, supported by the intact ossicular chain and the preserved facial ridge (Fig. **585**). In case

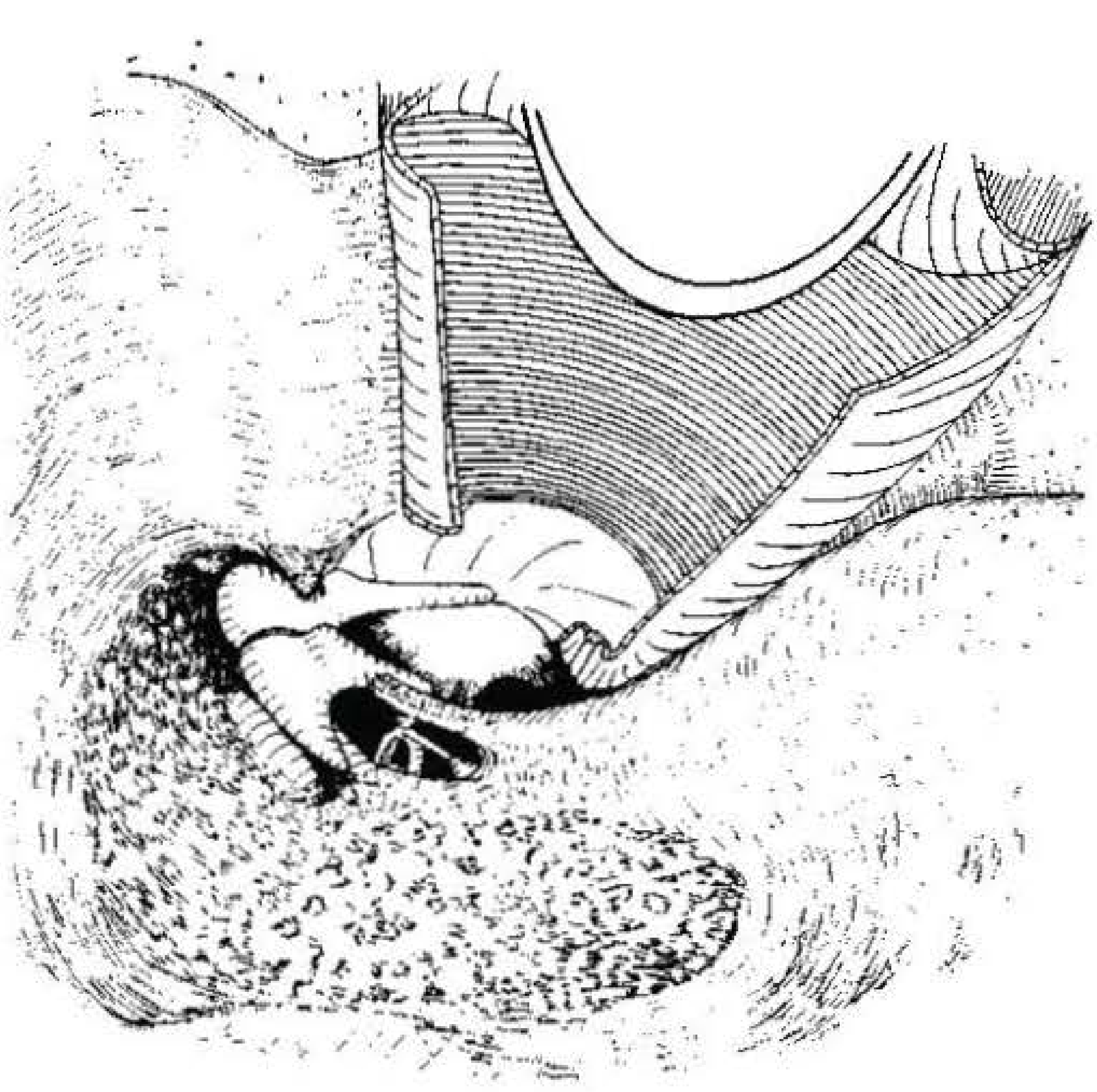


Fig. **592** **Partial preservation of the bridge.** In a case of sinus cholesteatoma, an anterior part of the bridge is preserved, preventing a retraction into the anterior attic. Instead of drilling away the posterior buttress, an atticotympanotomy is performed, preserving the posterior part of the bridge and providing better conditions for reconstruction of the tympanic cavity and ventilation of the attic with missing incus a preserved bony bridge (Fig. **594**) can provide good support for ossiculoplasty (Fig. **595**).

When the malleus head is missing or has been removed, it may sometimes be justified to leave the posterior part of the bony bridge (Fig. **596**) in order to provide easier conditions for ossiculoplasty, but it is better to remove the anterior overhang as far as the medial wall of the attic (Fig. **597**).

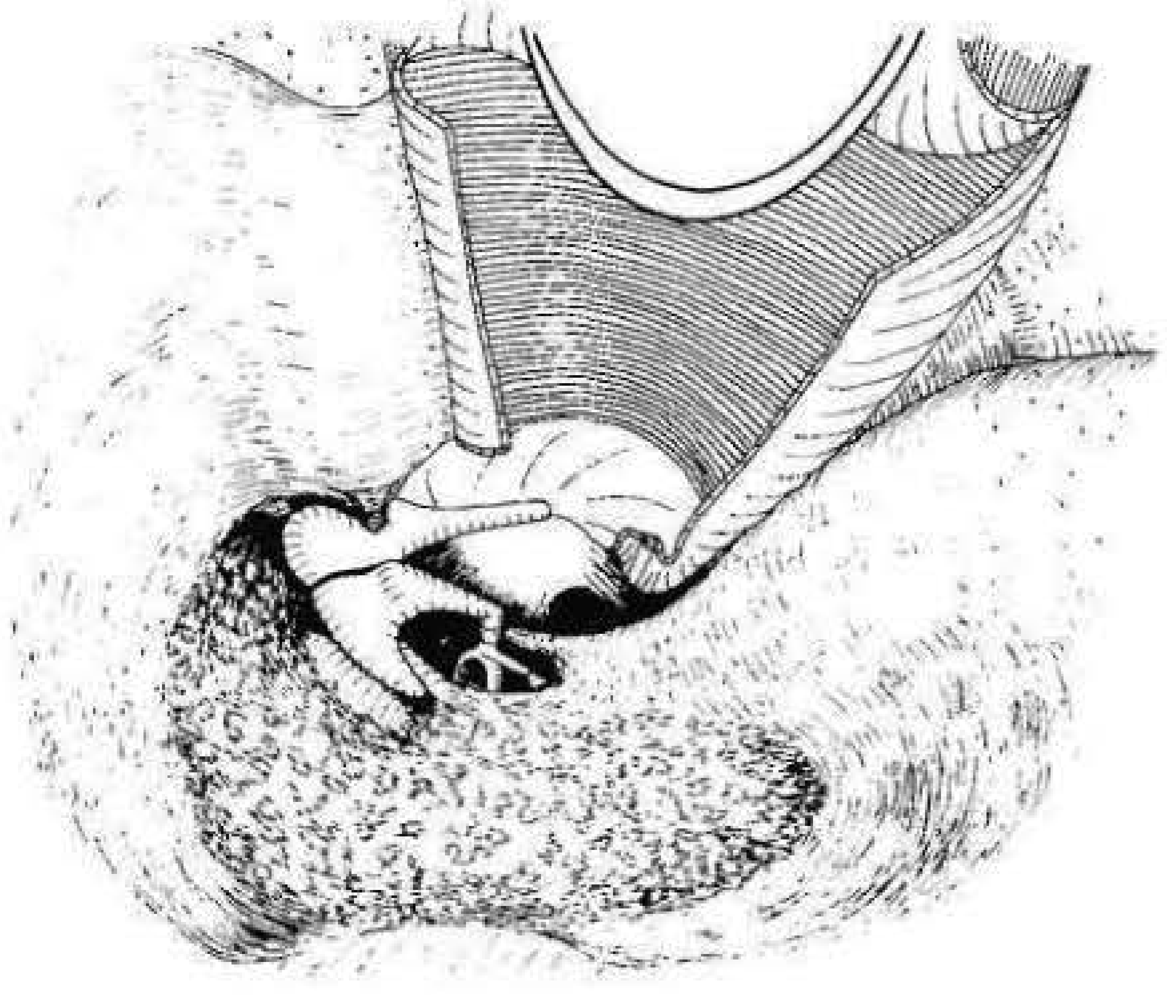


Fig. **593** **Only small parts of the bridge are preserved** anteriorly and posteriory, still maintaining a high tympanic cavity, especially in an intact ossicular chain

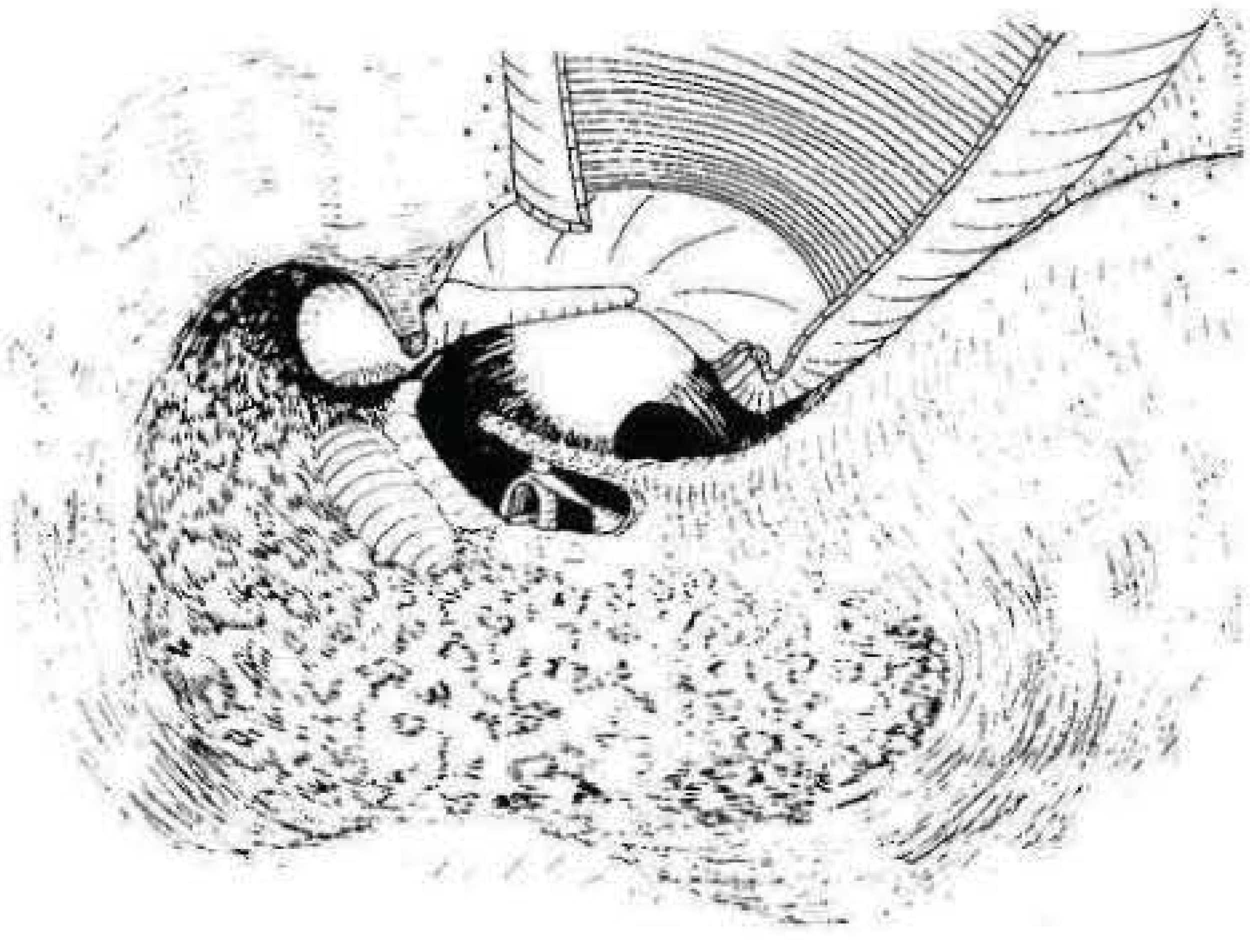


Fig. **594** The incus is missing, and the bridge has been preserved anteriorly and posteriorly by performing an posterior atticotympanotomy

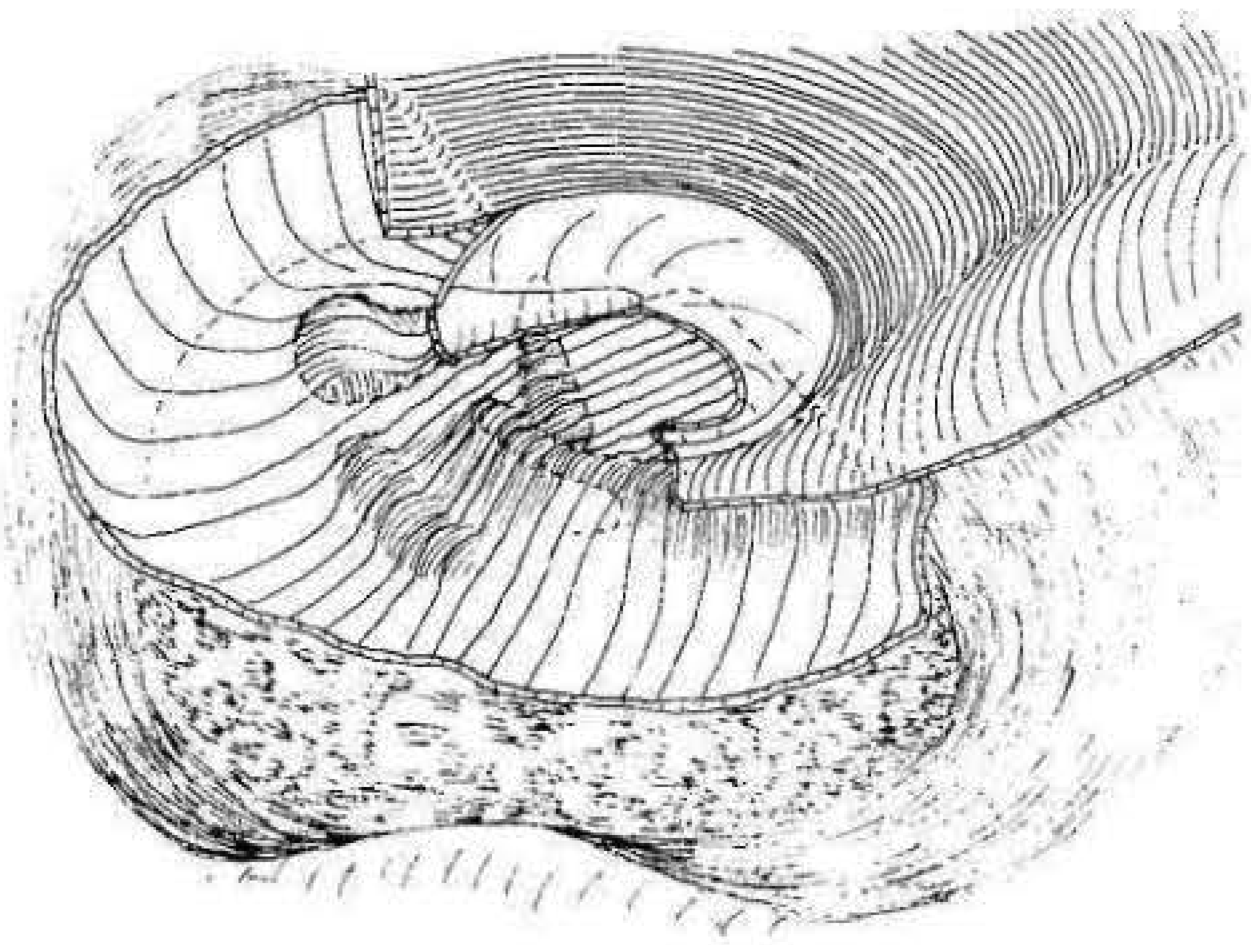


Fig. **595** After interposition of a piece of bone between the stapes and the malleus. The bridge can act as a support for the tympanic membrane, and the anterior attic can be ventilated

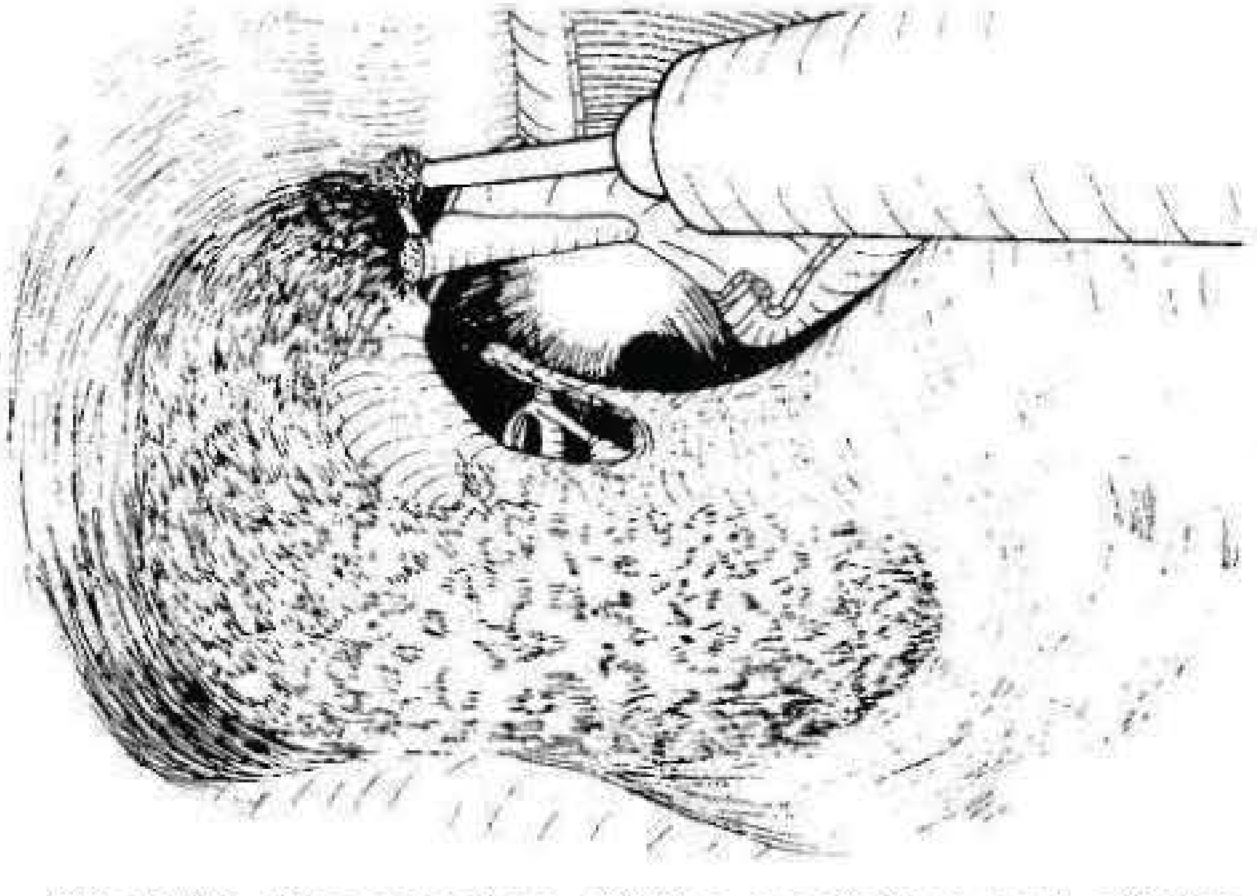


Fig. **596** **Preservation of the posterior part of the bridge** in a case with the malleus head removed. In such cases, the anterior buttress is further drilled away, preventing a narrow retraction. The attic is now wide open without any overhangs, but will probably not be ventilated

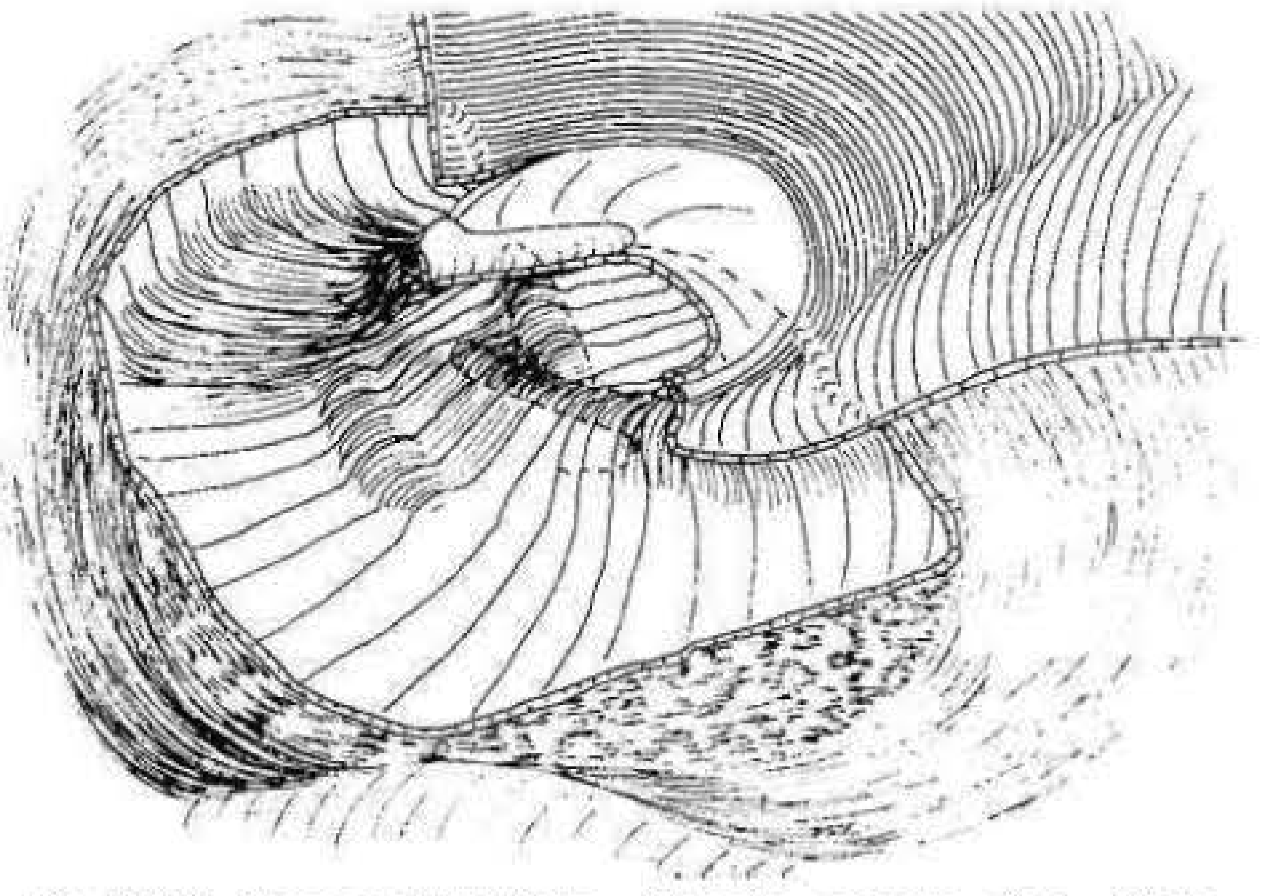


Fig. **597** **Reconstruction.** Fascia covers the interposed bony graft, the drum perforation, and the preserved bony bridge. The attic is not ventilated

Removal of Attic Cholesteatoma in Canal Wall–Down Mastoidectomy

Removal of an attic cholesteatoma with an intact ossicular chain, good hearing, and an intact pars tensa—a situation often seen—using Bondy's operation is described above in Figures **568** to **578**. Removal of attic cholesteatoma by marsupialization, leaving the medial part of the matrix in cases of attic cholesteatomas extending into the tympanic cavity, is also described in Figures **12** to **14**. The various problems encountered in elevation or removal of an attic cholesteatoma from the mastoid tegmen in cases with low dura are illustrated in Figures **131, 132, 134,** and **135.** Elevation of the cholesteatoma from the antrum and posterior fossa dural plate in cases with a prominent sigmoid sinus is shown in Chapter 4, Figures **152** to **155.**

Removal of the cholesteatoma from the perilabyrinthine cells is illustrated in Figures **186** to **188,** and removal of cholesteatoma from the sinodural angle and from an exposed superior petrosal sinus is shown in Figures **129** to **201.** Removal of cholesteatoma and exenteration from the perilabyrinthine cells, especially in childhood cholesteatoma, is illustrated in Chapter 4, Figures **119** to **239.** These basic techniques of cholesteatoma removal are independent of whether canal wall–down or canal wall–up mastoidectomy is performed, but it is evident that cholesteatoma removal is easiest and safest in canal wall–down mastoidectomy, which remains the main reason why canal wall–down mastoidectomy is the most commonly employed method today.

Attic cholesteatoma in canal wall–down mastoidectomy can be isolated without opening the sac, so that all the bone lateral, superior, and inferior to the cholesteatoma sac, including the bony ear canal, is removed, and the cholesteatoma is elevated in toto, in contrast to the classic canal wall–up and modified canal wall–up mastoidectomies, where the removal of the attic cholesteatoma is a more complicated procedure (see Chapters 6 and 7).

After removal of the bony ear canal wall, the outher border of the attic retraction is clearly visible, and the lateral wall of the cholesteatoma sac is exposed (Fig. **598**). After a posterior tympanotomy has been performed, the extension of the cholesteatoma into the posterosuperior part of the tympanic cavity, usually eroding the long process of the incus, leaving only the lenticular process attached to the stapes, is then demarcated. The anterior remnants of the bridge and the anterior buttress are removed, exposing the cholesteatoma anterior to the malleus head (Fig. **598**).

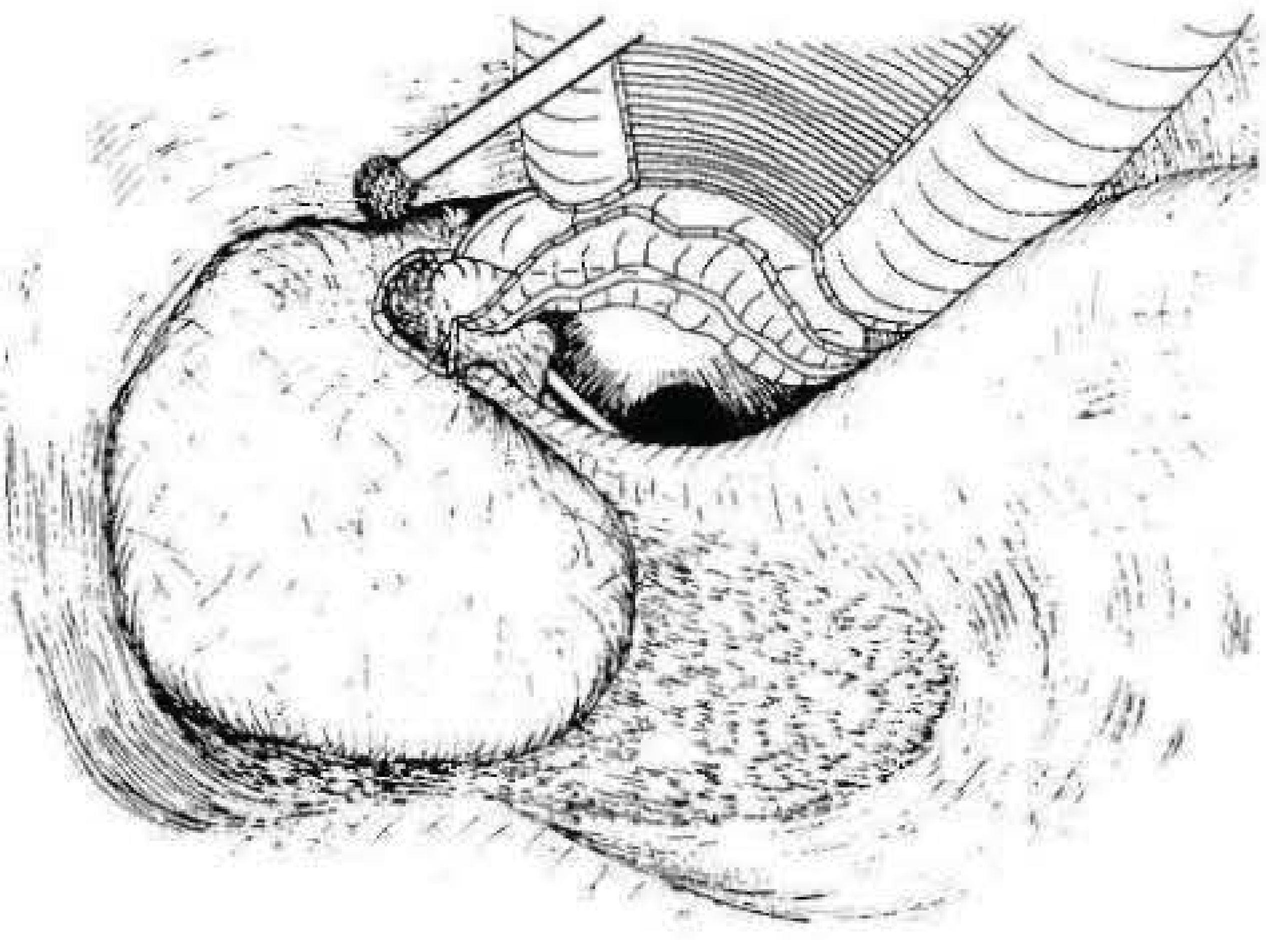


Fig. **598** **Removal of an attic cholesteatoma in canal wall-down mastoidectomy.** The bony ear canal wall and the bridge are removed, and the cholesteatoma sac is exposed and demarcated from the surrounding bone. The anterior attic wall is further removed, exposing the anterior part of the cholesteatoma sac. The posterior tympanomeatal flap is elevated, and a defect in the long process of the incus can be recognized, as well as cholesteatoma extension to the mesotympanum

The posterior part of the bony bridge is removed (Fig. **599**), and the cholesteatoma in the tympanic cavity is exposed and elevated from the stapes. The entire cholesteatoma sac can now be elevated, with a search being made for any fingerlike protrusions extending into the perilabyrinthine cells. If the perilabyrinthine space is sclerotic, the cholesteatoma can be elevated in toto, exposing the lateral semicircular canal, dislocating the incus body, and cleaning the malleus head (Fig. **600**). If the cholesteatoma can be safely removed from the malleus head, it is preserved (Fig. **601**); if not, the malleus head is resected together with the cholesteatoma. The tympanic cavity is now clean, and can be reconstructed by preserving the lenticular process attached to the stapes head and placing the fascia onto the lenticular process and onto the malleus head (Fig. **602**). The attic can be ventilated, and the cavity can remain an open one if it is small, or if larger it can be obliterated.

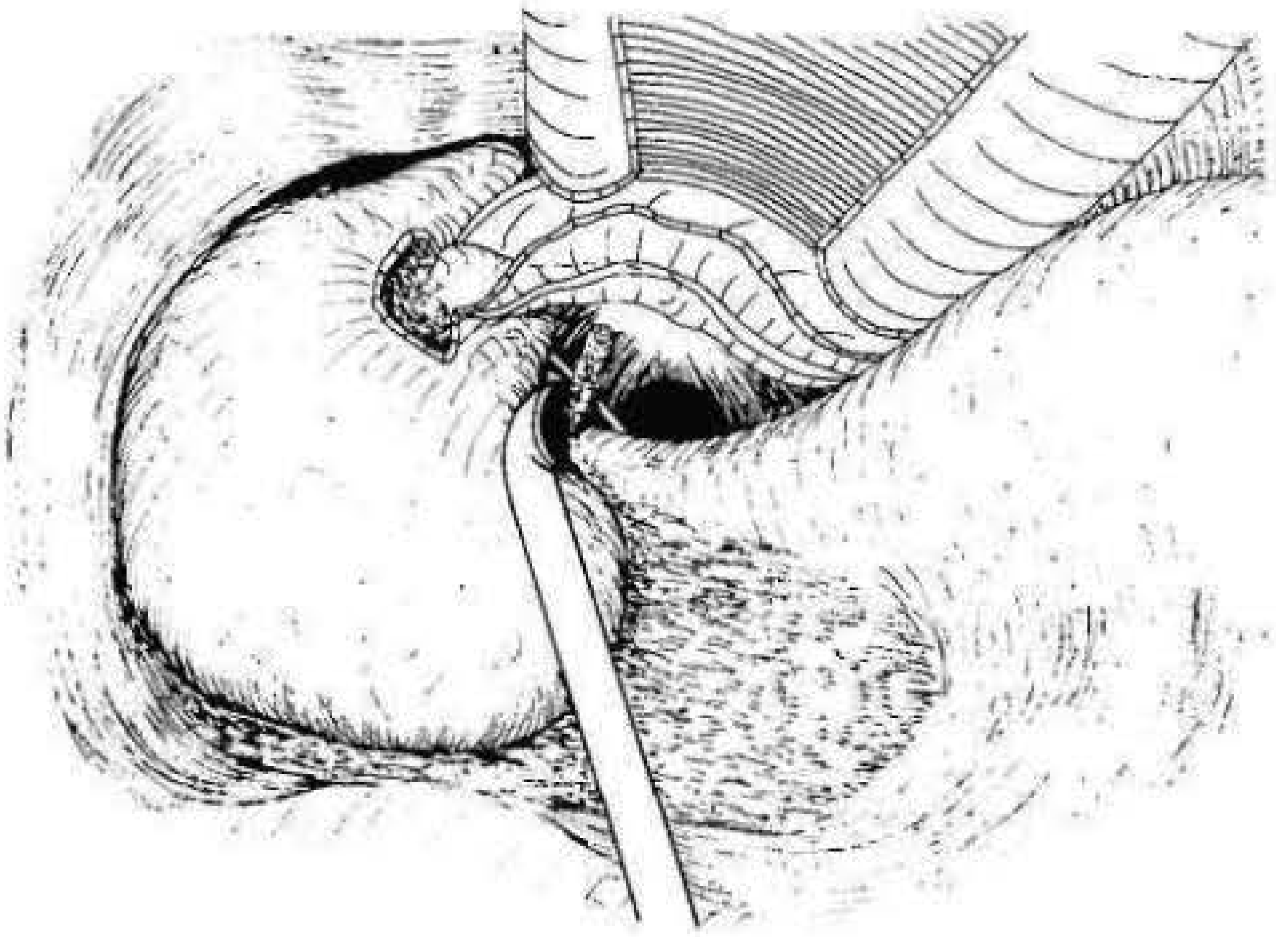


Fig. **599** The anterior buttress is removed, the posterior bridge remnant is fractured out using a curet, and the entire sac is ready to be removed in toto

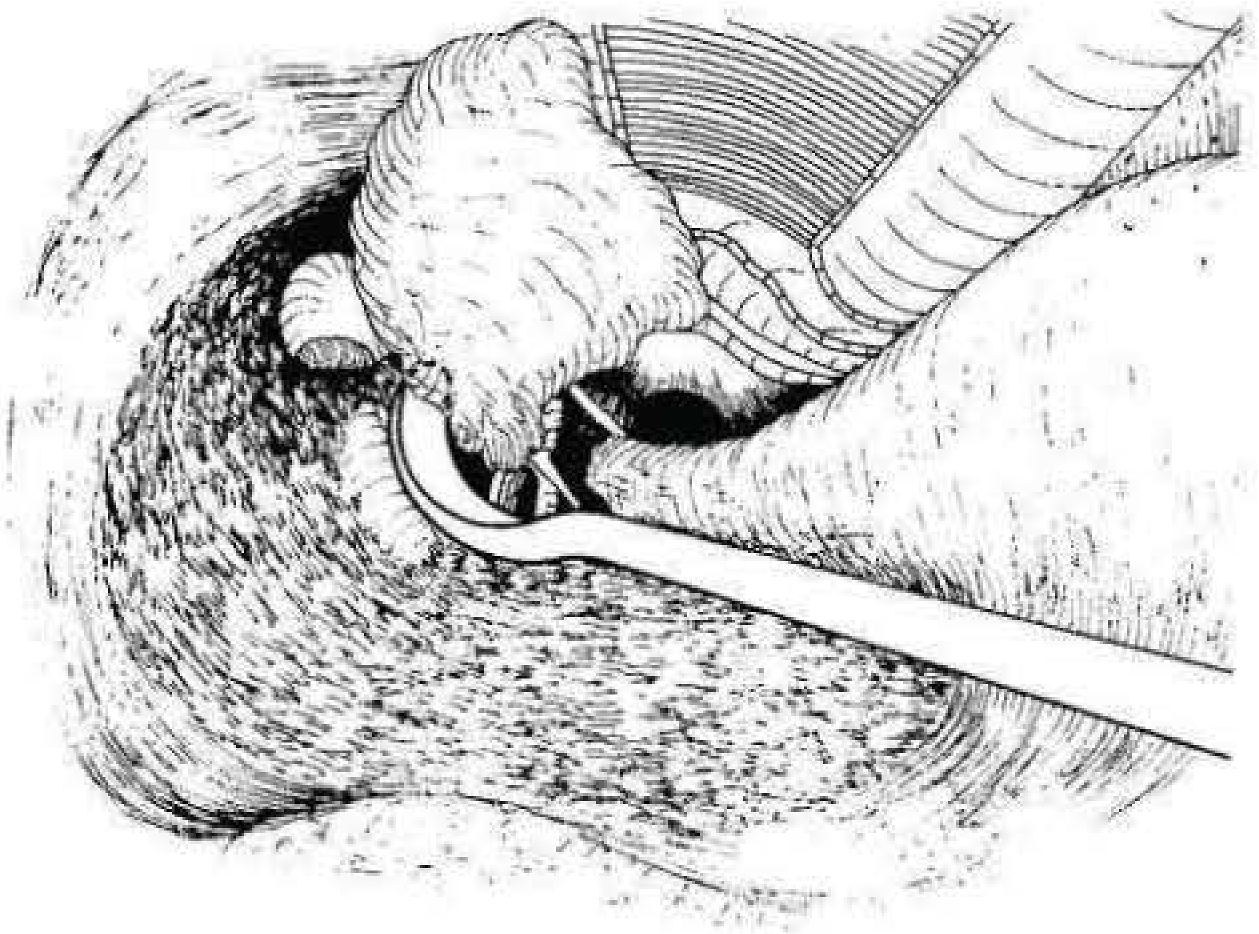


Fig. **600** The entire attic cholesteatoma sac is elevated, exposing the lateral semicircular canal and luxating the incus body from the malleus head

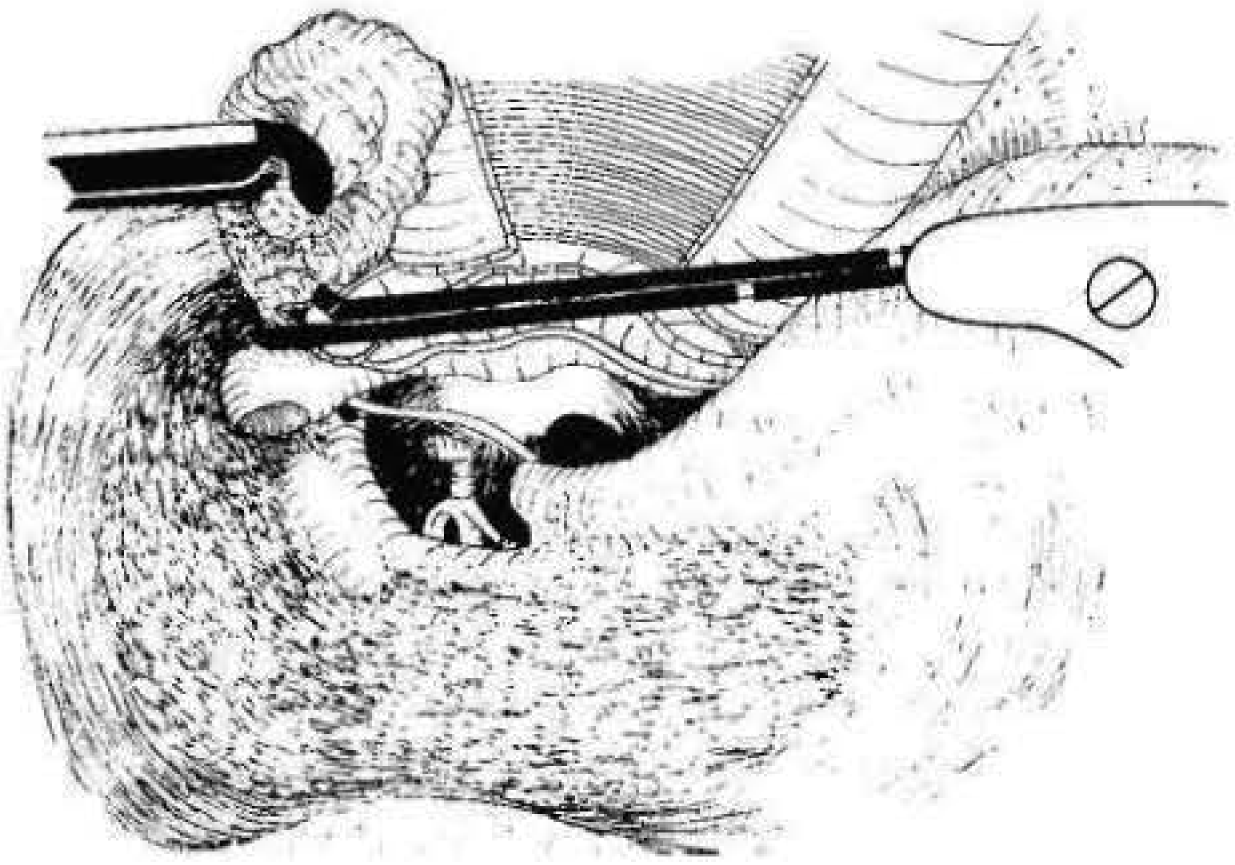


Fig. **601** The malleus head is preserved and cleaned, the lenticular process is attached to the stapes, and the cholesteatoma sac is removed in toto

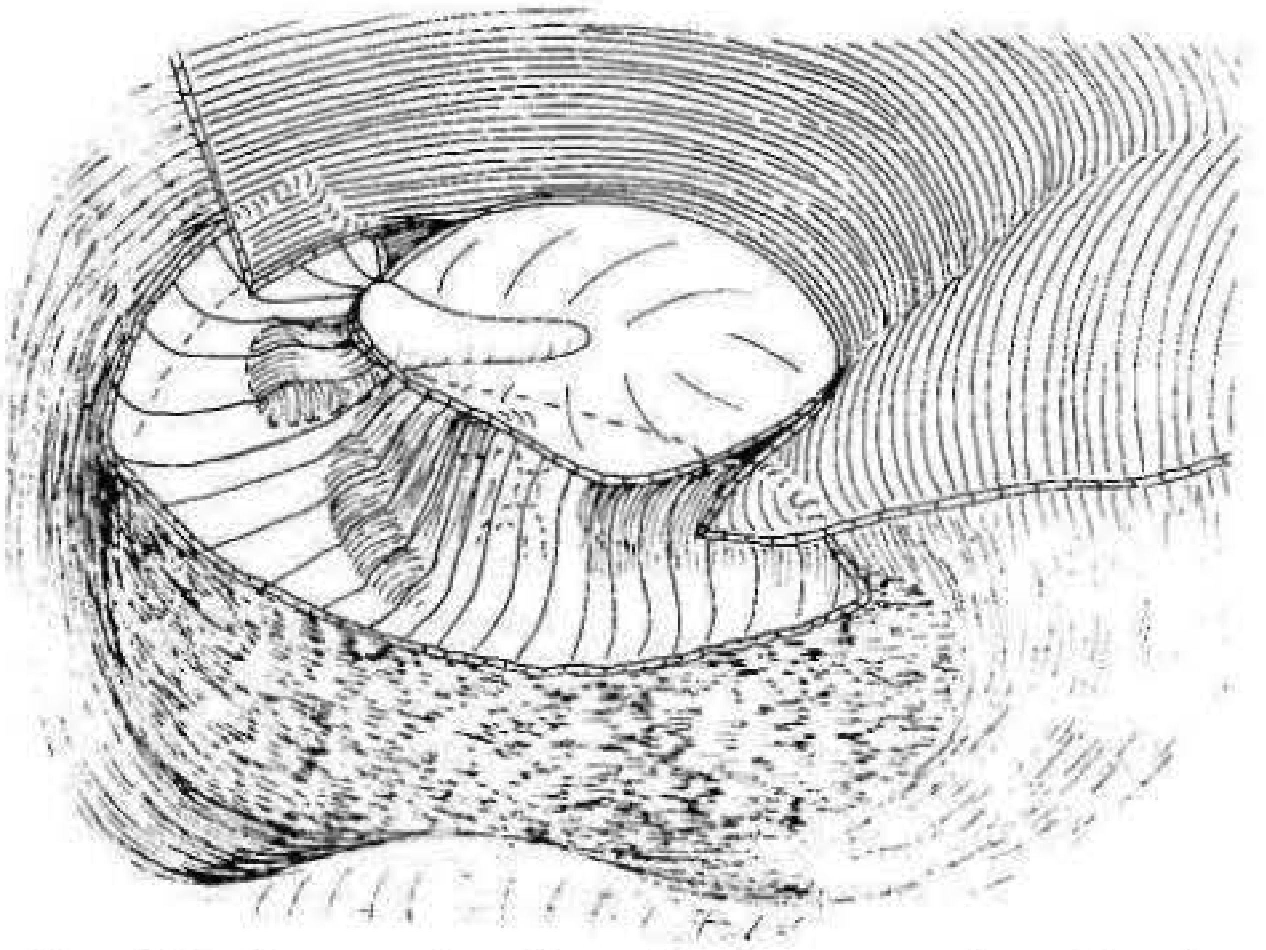


Fig. **602** **Reconstruction.** Fascia covers the attic, the malleus head, the lenticular process, and the facial ridge

Removal of Sinus Cholesteatoma in Canal Wall–Down Mastoidectomy

Sinus cholesteatoma, defined as a retraction or perforation of the posterosuperior part of pars tensa, surrounds the stapes and extends into the tympanic sinuses. The long process of the incus is usually resorbed, and the cholesteatoma may extend medial to the incus body up to the attic (Fig. **603**). Sinus cholesteatomas are usually not large, and can be removed relatively easily in canal wall–down mastoidectomy. After removal of the bony ear canal wall and the bony bridge, the cholesteatoma located in the attic and aditus ad antrum is isolated from its surroundings and elevated together with the incus (Fig. **604**). After removal of the incus, good exposure is achieved of the horizontal part of the facial nerve, and after lowering of the facial ridge and removal of the posterior buttress, the genu of the facial nerve is skeletonized, providing good exposure of the tympanic sinuses. The cholesteatoma membrane covering the mesotympanum, the facial nerve, and the sinus tympani is elevated and gradually removed (Fig. **605**).

Reconstruction is illustrated in Figure **589.**

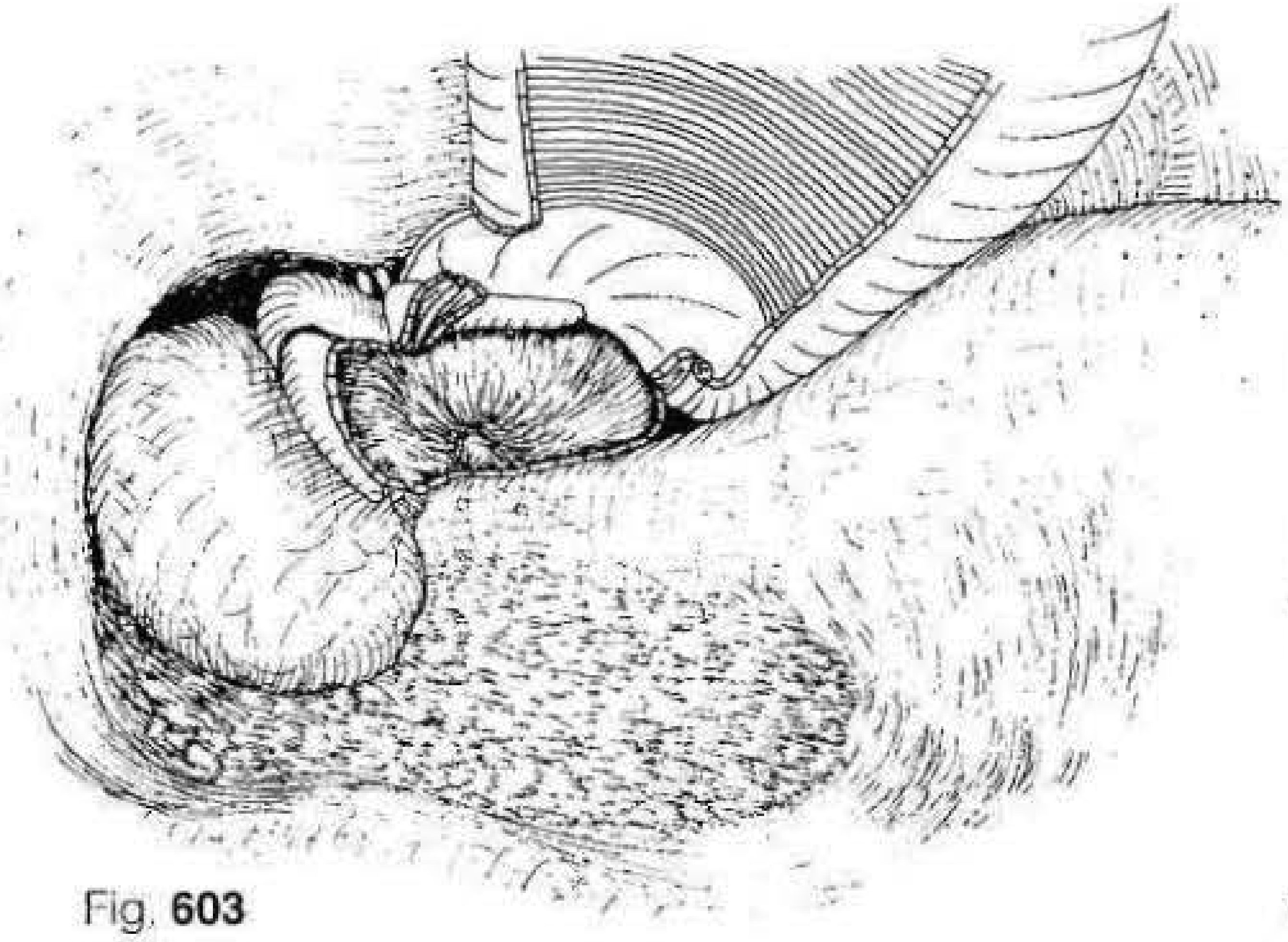


Fig. 603

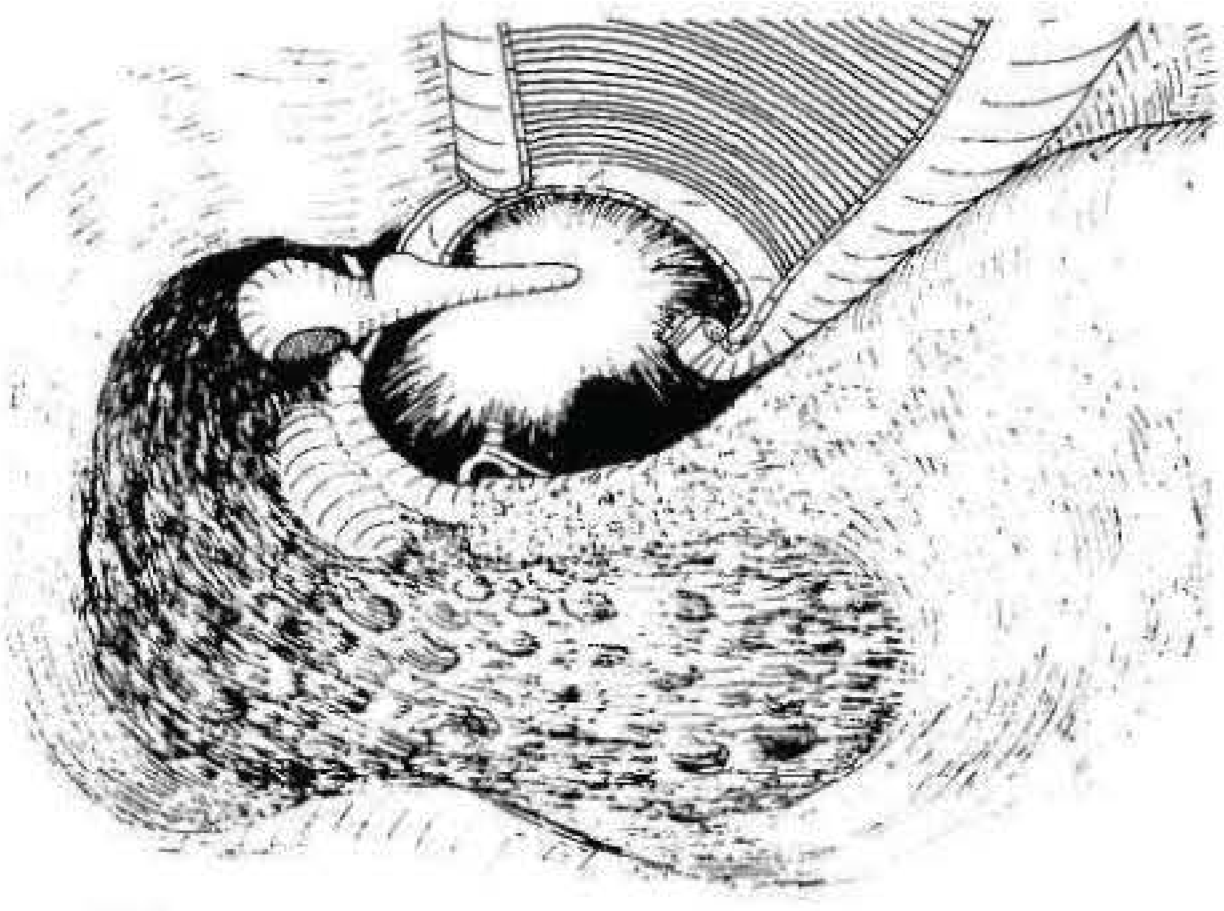


Fig. 604

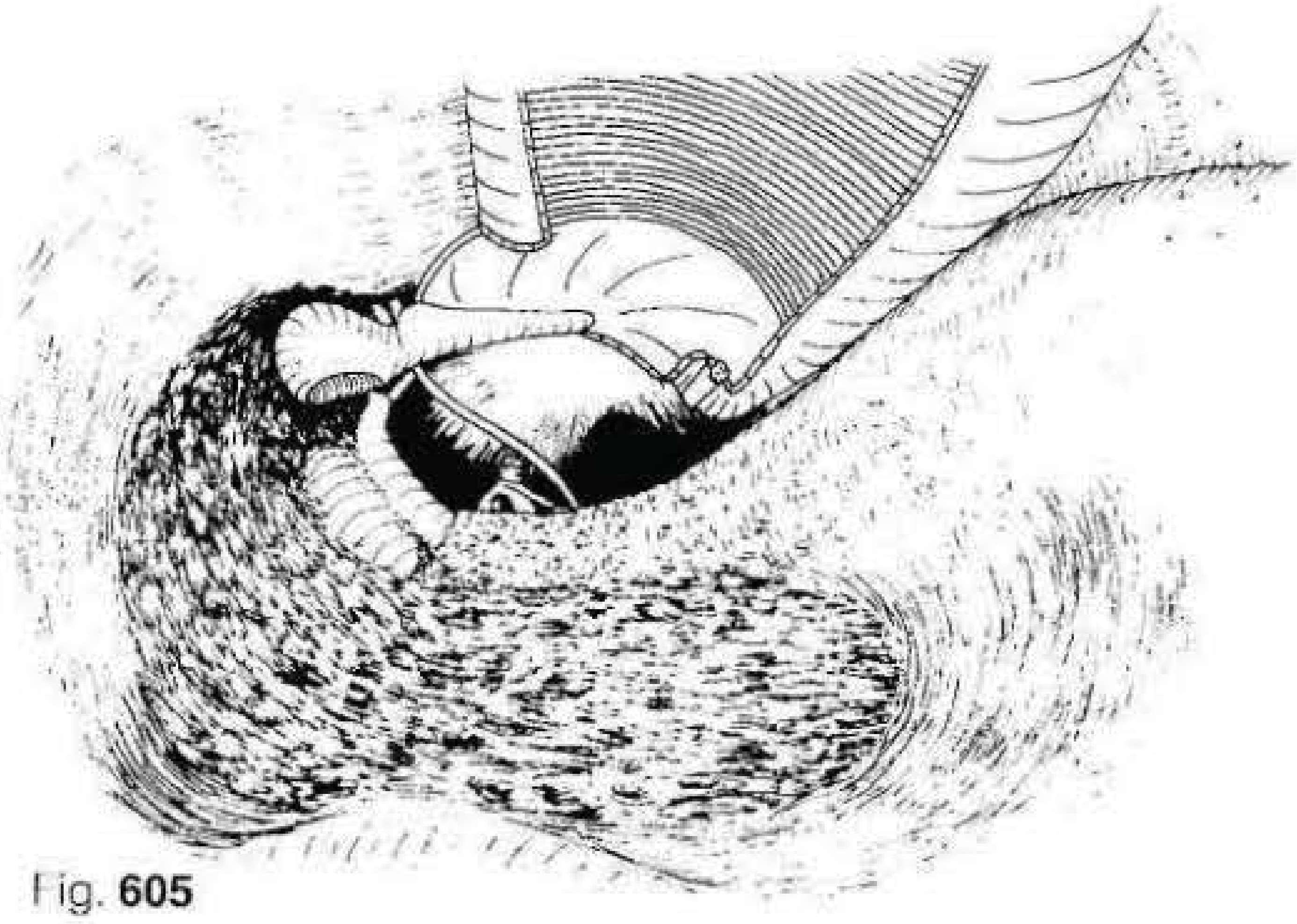


Fig. 605

Fig. **603** **Removal of a sinus cholesteatoma in a canal wall–down mastoidectomy.** A sinus cholesteatoma indicating a posterosuperior retraction involving the tympanic sinuses and extending medial to the incus body and malleus head into the attic. The anterior buttress is removed, the facial ridge is lowered, and the cholesteatoma is demarcated

Fig. **604** The incus is removed together with the cholesteatoma. There is still a cholesteatoma matrix attached to the facial nerve, and to the sinuses, posterior tympanum, and stapes as well. It will be gradually elevated from all sides after lowering of the facial ridge and exposure of the tympanic sinuses

Fig. **605** The final result after removal of the sinus cholesteatoma is a low facial ridge and skeletonized genu of the facial nerve. The malleus head is preserved

Removal of Tensa Retraction Cholesteatoma

Tensa retraction cholesteatoma is defined as a retraction of the entire pars tensa. It is adherent to the promontory, hypotympanum. tympanic sinuses, and tubal orifice. The cholesteatoma surrounds the malleus handle, which is often resorbed, and can continue under the malleus head and incus body up into the attic (Fig. **606**). In canal wall–down mastoidectomy with removal of the bridge, the entire cholesteatoma membrane is elevated from the medial attic wall and lateral semicircular canal together with the incus body. The cholesteatoma membrane is removed from the tympanic cavity. The malleus head often needs to be resected because the cholesteatoma is located medially to it (Figs. **607, 608**). If the cholesteatoma is successfully elevated from the anterior attic, the malleus head can be left in place (Fig. **609**).

The tympanic cavity can be reconstructed using a large piece of fascia covering the total perforation, and interposition of a bony graft between the stapes and the malleus handle. Usually, the fascia covers the medial attic wall, which is therefore not ventilated (Fig. **610**).

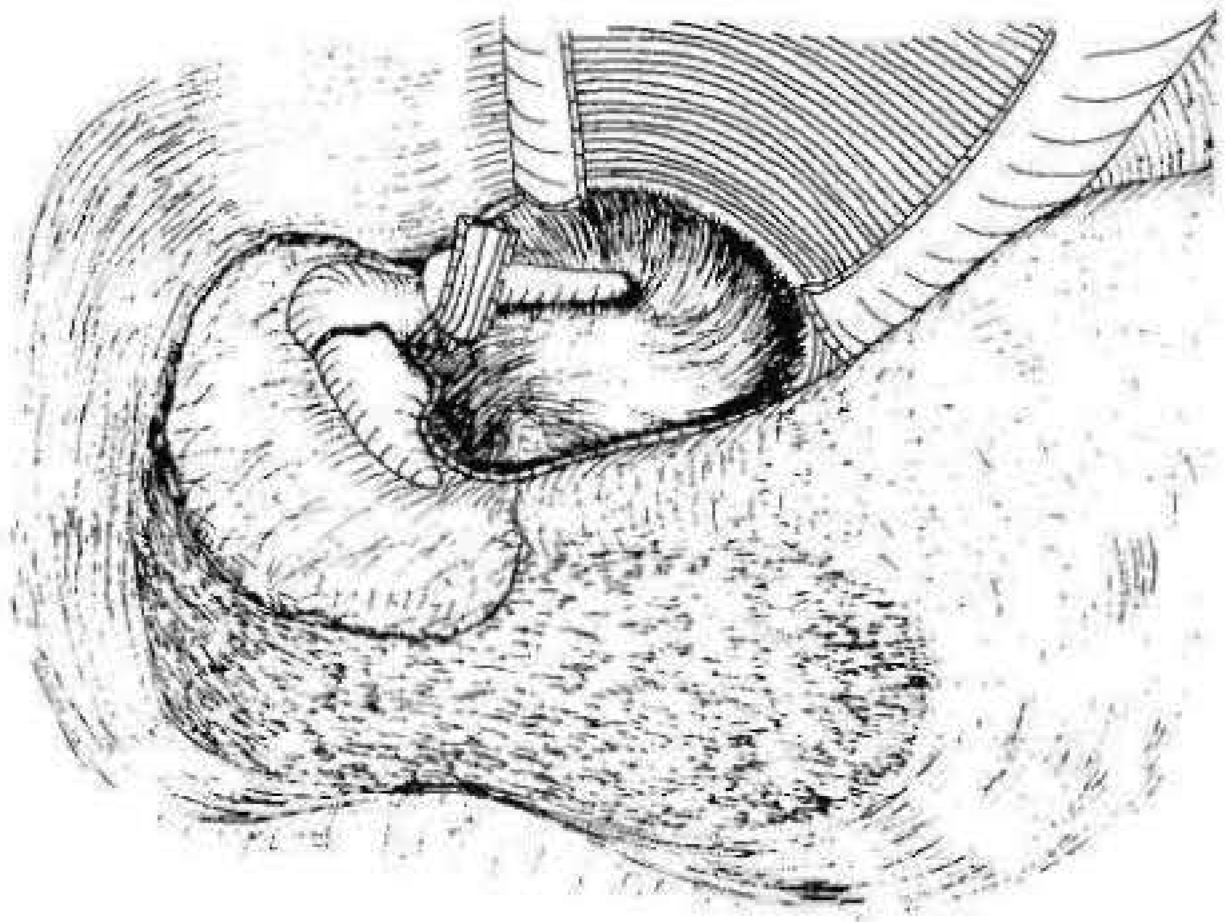


Fig. **606** **Removal of a tensa retraction cholesteatoma in canal wall–down mastoidectomy with removal of the bony bridge.** A tensa retraction cholesteatoma, indicating retraction and adhesion of the entire pars tensa to the promontory, posterior tympanum, tympanic sinuses, and tubal orifice. The cholesteatoma extends into the attic medially to the malleus head and incus body

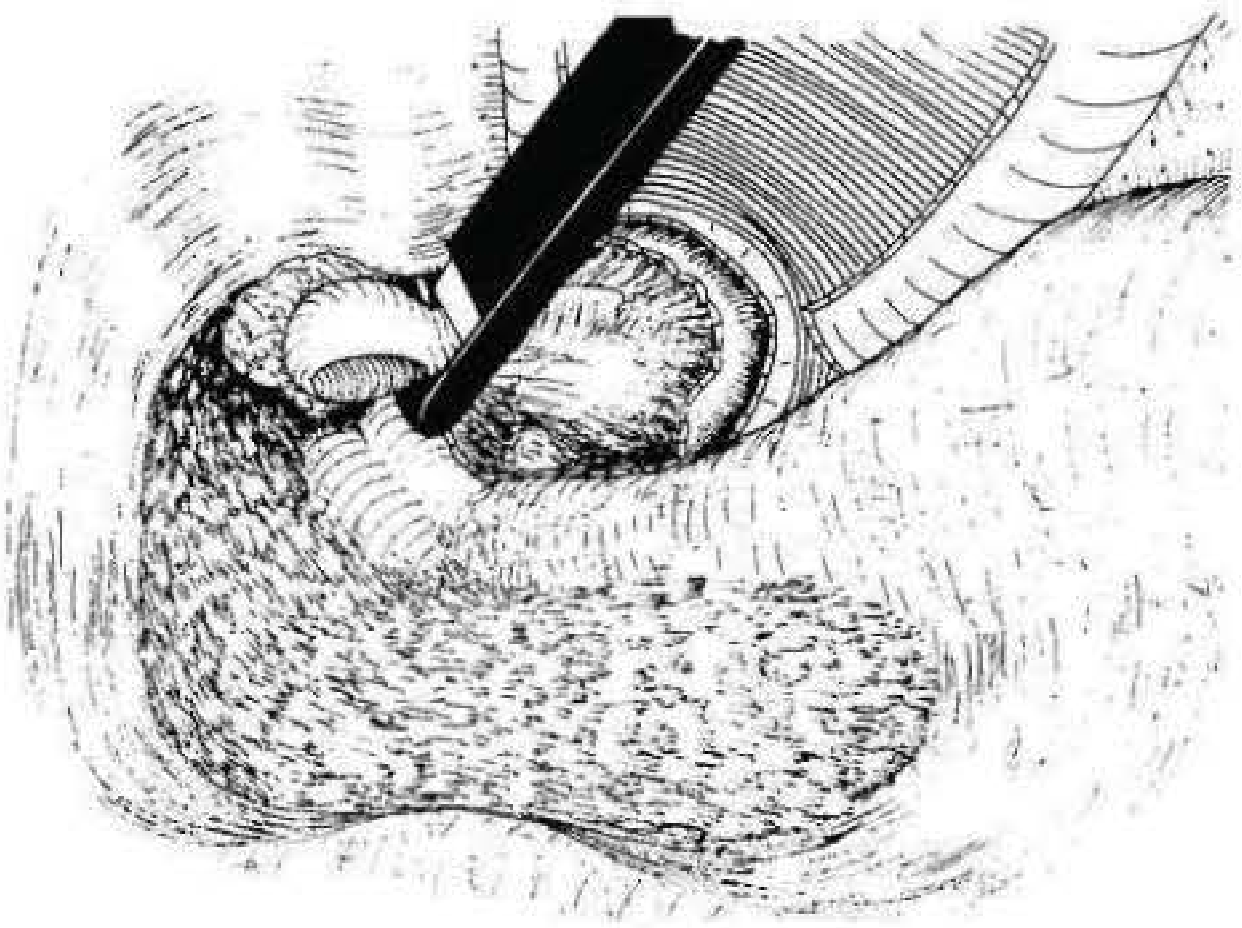


Fig. **607** The cholesteatoma is elevated from the medial attic wall, the incus body is removed and the malleus head is resected with a punch

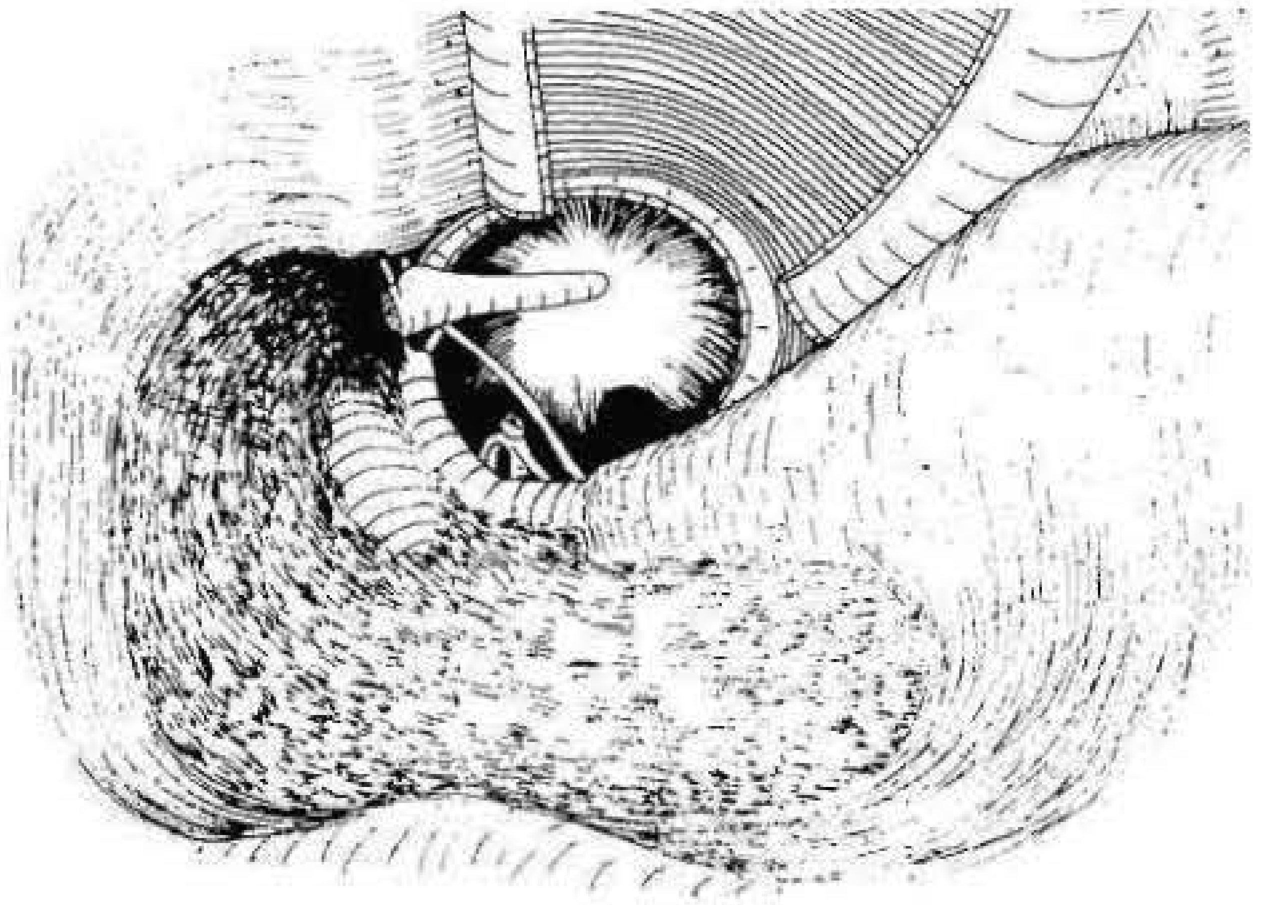


Fig. **608** **The situation after removal of the tensa retraction cholesteatoma.** A total perforation and a preserved malleus handle. After ossiculoplasty, the attic is not ventilated

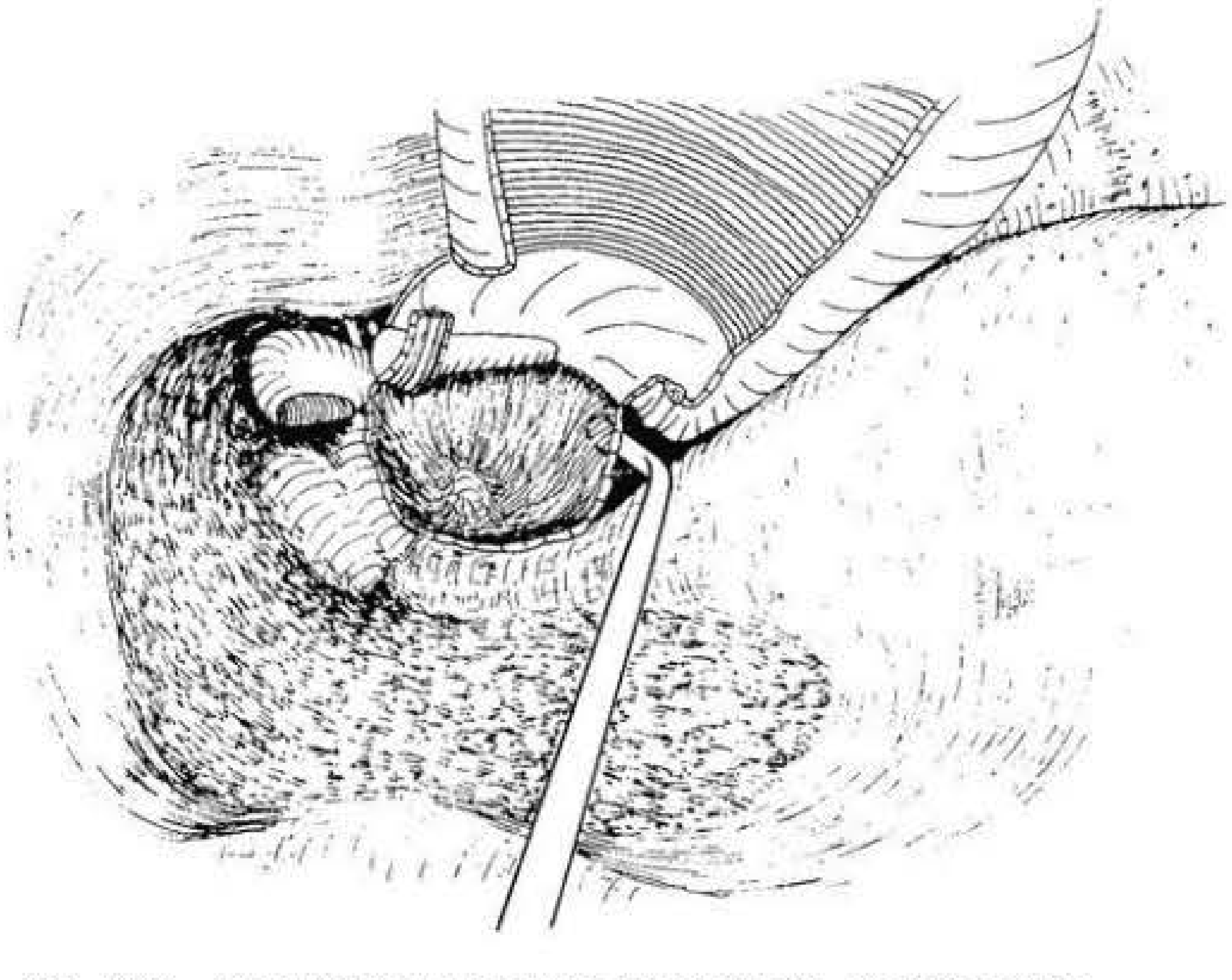


Fig. **609** The malleus head is preserved, and the anterior attic can be ventilated after reconstruction of the tympanic cavity

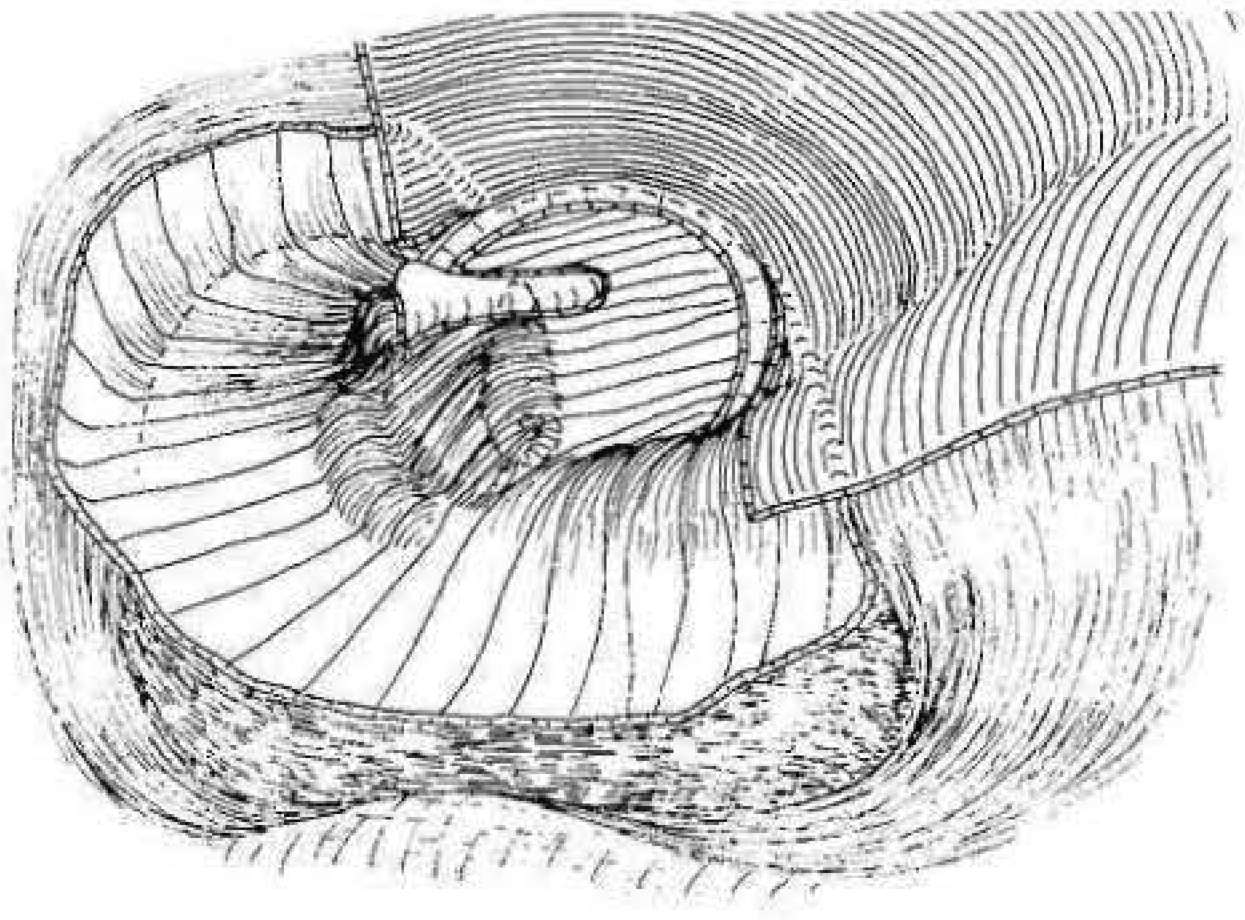


Fig. **610** **Reconstruction.** Fascia covers the total perforation as an underlay graft, with an interposed piece of bone. The attic is not ventilated

Preservation of an Intact Bridge

In addition to the methods of preservation of the soft meatal wall, described in Chapter 6 (Figs. **255** to **259**), some surgeons in the 1940s and 1950s performed conservative radical operations, recommending preservation of the bony bridge (Dagget 1949, Sheridan 1943, 1950). Dagget (1949) used several surgical methods: 1) preservation of the bony bridge (Fig. **255**), including all the ossicles, 2) preservation of a thin bridge with the incus removed; and 3) bridge preserved with the incus and malleus head removed (Fig. **256**). Similar techniques with the bridge preserved were used by Andrew (1956) (Fig. **258**). Jongkees (1957), using an endaural or retroauricular incision, often preserved the entire bridge intact to support the drum and give it tension.

Preservation of the bony bridge with a posterior atticotympanotomy is mainyl used in sinus cholesteatoma and tensa retraction cholesteatoma, because in these types of cholesteatoma there is no resorption of the lateral attic wall, as there is in attic cholesteatoma. The ear canal is removed as far as the bony bridge; the facial ridge is lowered and sculpted (Fig. **611**). A posterior atticotympanotomy, exposing the stapes, is performed. As early as the 1950s Jongkees (1957) was widely using this technique, creating a window through the facial recess. The posterior buttress is removed (Fig. **611**). The anterior part of the bony ear canal is removed, and the transition from the anterior bony ear canal wall to the anterior wall of the cavity is completely smoothed (Fig. **612**). Finally, the posterior atticotympanotomy is enlarged, making the bony bridge thin (Fig. **613**).

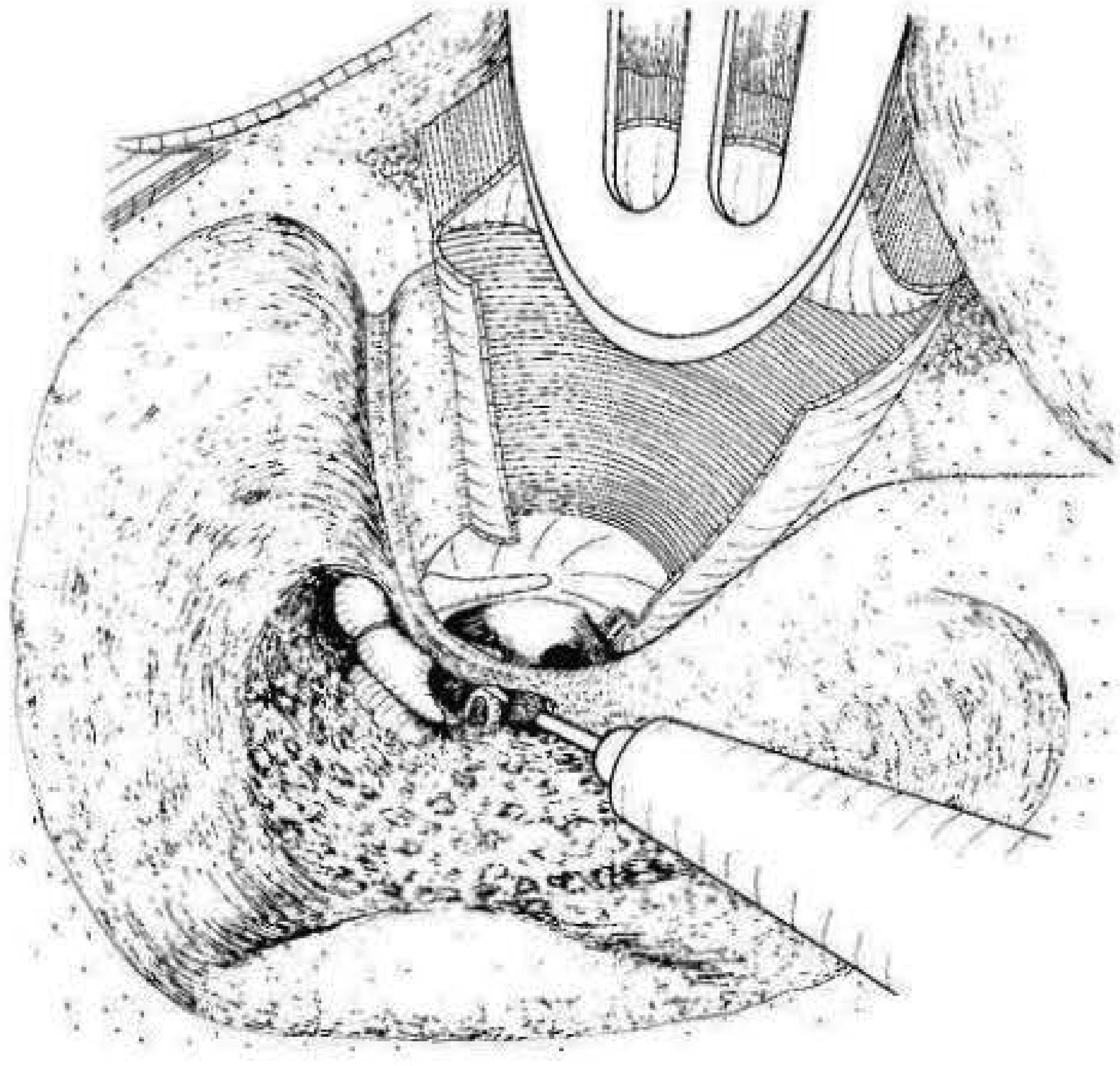


Fig. **611** **Canal wall–down mastoidectomy with preservation of the bony bridge.** The posterior ear canal wall is removed, preserving a bridge all the way around. The facial ridge is smoothed and lowered, and a posterior atticotympanotomy is performed, with the stapes and tympanic sinuses being inspected

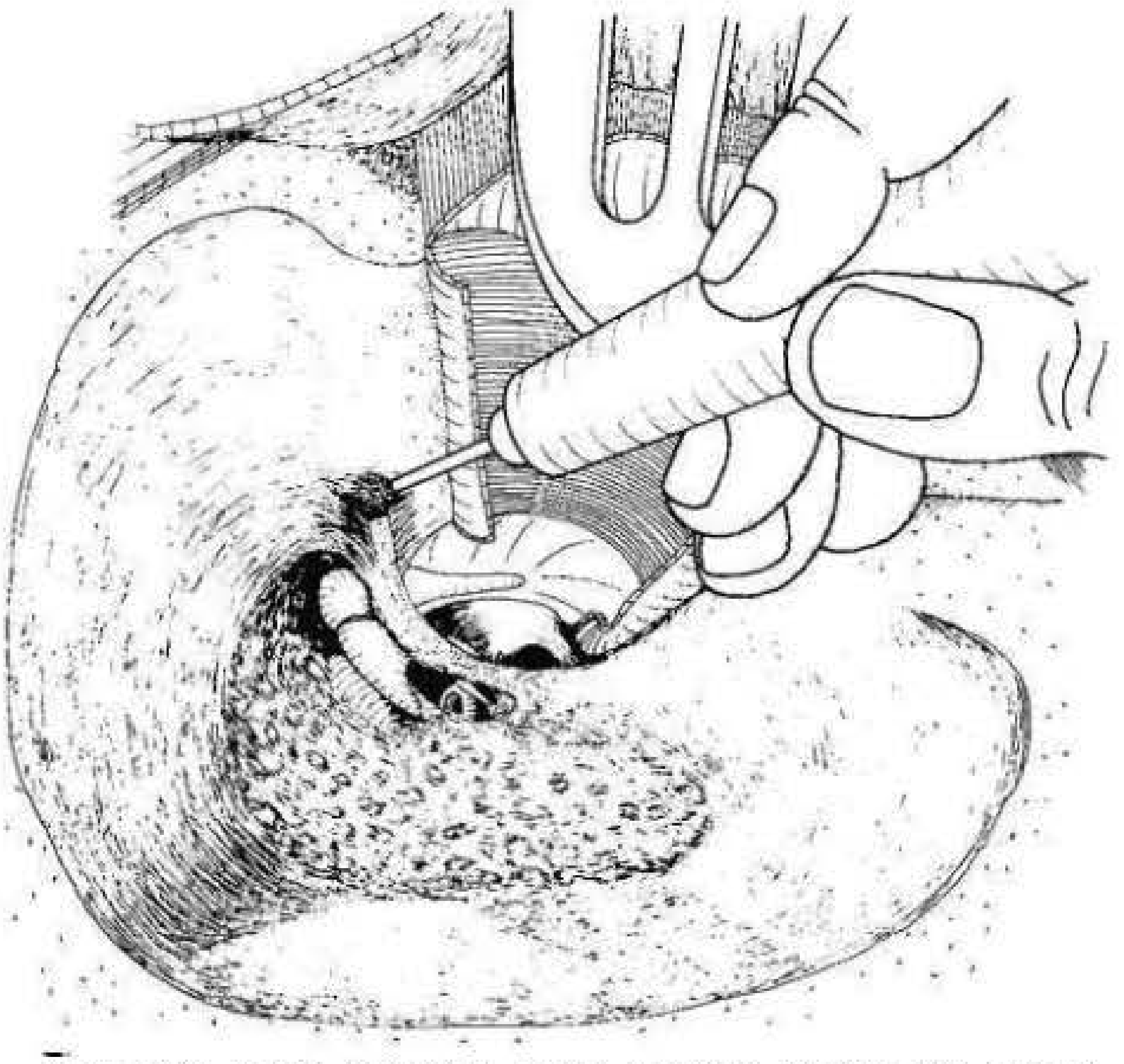


Fig. **612** The anterior edge of the bony ear canal, attached to the zygomatic region, is removed, and the anterior meatal wall is smoothed, providing a smooth transition from the anterior ear canal wall to the anterior wall of the mastoid cavity

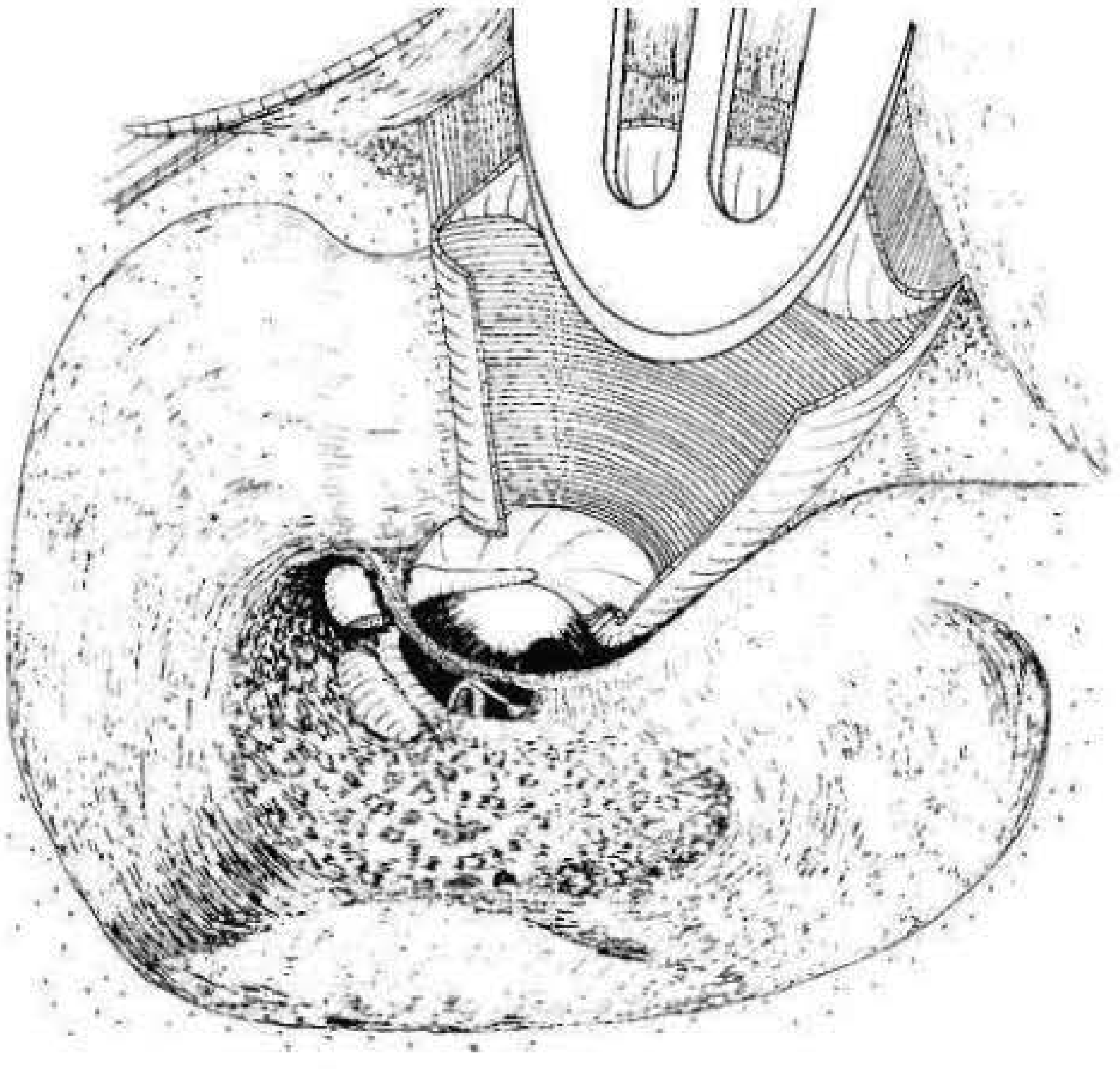


Fig. **613** The facial ridge and the anterior zygomatic region are smoothed, the remaining bony bridge is thinned, and the posterior tympanotomy is completed with removal of the incus

The purpose of preserving the bony ear canal is to maintain a high tympanic cavity, support the fascia graft, and create better conditions for ossiculoplasty. The risk is residual cholesteatoma and retraction through the facial recess.

Displacement of the Intact Bridge

If the lateral attic wall is spontaneously eroded by an attic cholesteatoma, if the posterosuperior bony annulus is eroded by a sinus cholesteatoma or tensa retraction cholesteatoma, or if a previous intact canal wall technique has been performed with some removal of the bony annulus, then the original position of the bridge cannot be maintained. However, a bridge can still be preserved, if desired, in a canal wall–down mastoidectomy, and a bridge of this type will be displaced superolaterally (Figs. **49, 50**). A superolaterally displaced bridge can be achieved by removal of the bony ear canal wall, leaving and sculpturing the remnant of the bridge in a more superior position. The superolaterally displaced bridge provides good support for the fascia graft and for eventual reconstruction of the bony ear canal wall.

A partly preserved but displaced bridge can also sometimes be useful for ventilation of the anterior attic (Fig. **614**).

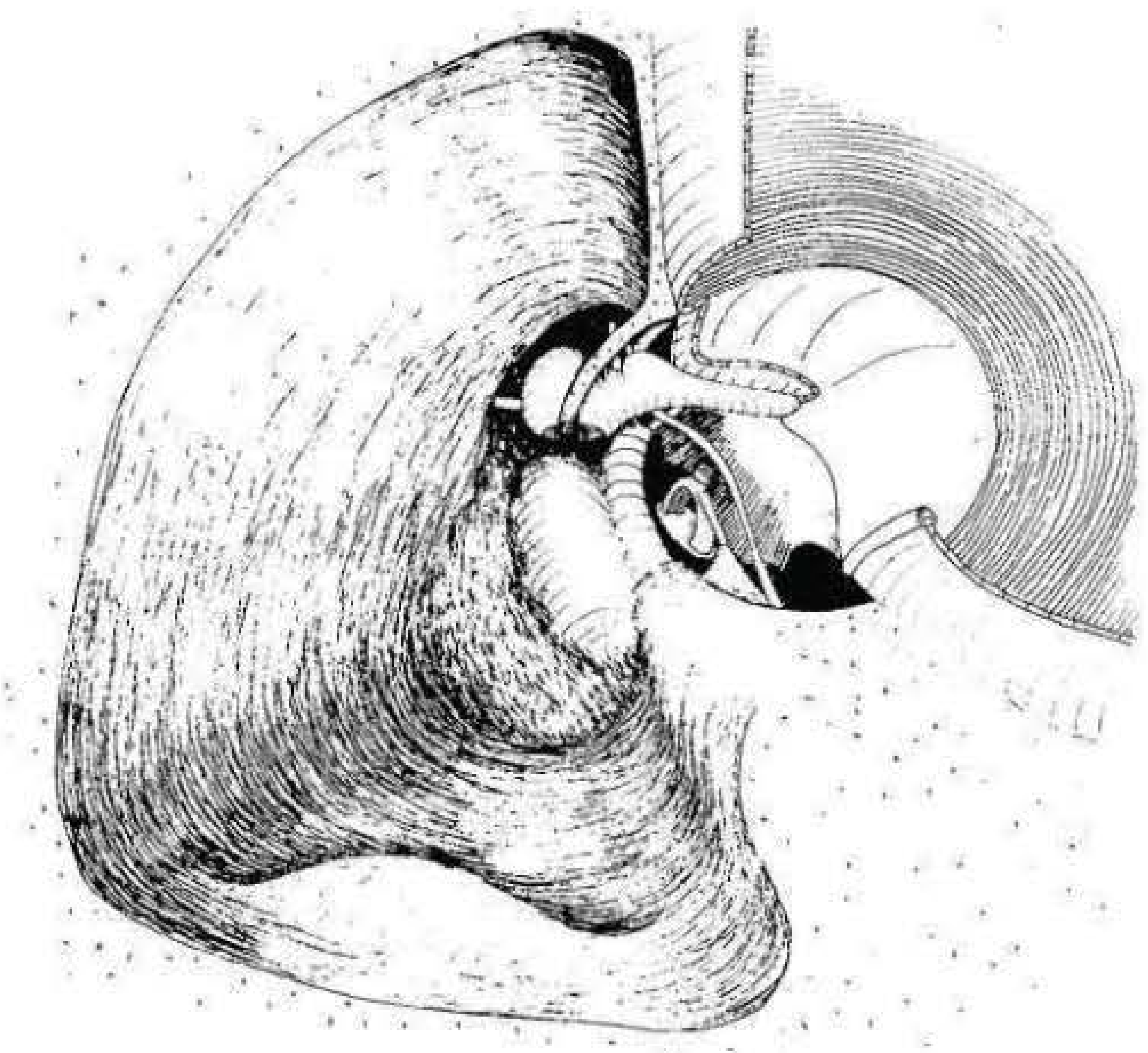


Fig. **614** **Displacement of the bridge.** A partially preserved bridge is displaced superiorly in a situation with a preserved malleus and canal wall–down mastoidectomy, with a low facial ridge

12 Transmeatal Canal Wall–Down Mastoidectomy

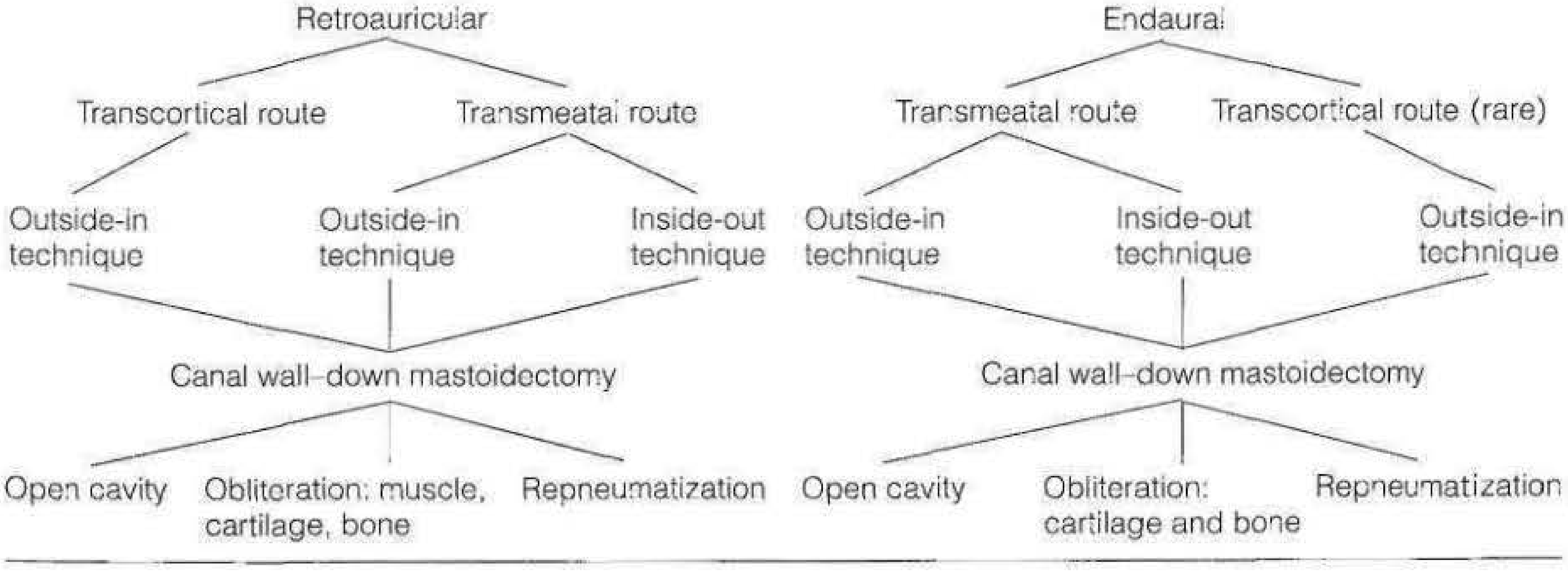
Definitions

Transmeatal canal wall–down mastoidectomy starts in the ear canal, in contrast to transcortical mastoidectomy, which starts on the mastoid plane posterior to the suprameatal spine. In transmeatal mastoidectomy, the ear canal wall, is taken down at the same time as the mastoidectomy, in contrast to cortical mastoidectomy, in which the bony ear canal is initially preserved, and is taken down after removal of Körner's septum and after atticoantrotomy. The results, however, of these two routes are basically the same, i. e., a cavity with either a low or a high facial ridge, with or without preservation of the bridge. The results are also the same whether the transmeatal route starts with removal of the ear canal laterally (the outside-in technique, Fig. **25**) or medially at the bony annulus (the inside-out technique). The bridge can be preserved in both routes, and the facial ridge can be low or high in either (Figs. **25, 26**).

Transmeatal canal wall–down mastoidectomy can be performed using a retroauricular approach (Fig. **24**) or an endaural approach (Fig. **25**). The retroauricular approach provides better access for surgery in the mastoid tip and around the sigmoid sinus (Table **8**). Surgery at the isthmus of the Eustachian tube is easier to perform with a retroauricular approach rather than an endaural one. The endaural approach is faster, more direct, and a more natural approach for transmeatal canal wall–down mastoidectomy. However, a difference in the appearance of the cavities results using either the retroauricular approach or the endaural one. In the retroauricular approach, the cavity is laterally larger and wider than in the endaural approach (Figs. **27, 28**), but the medial appearance of the cavity and its relation to the facial ridge or the bridge is generally the same.

In the retroauricular approach, there are more opportunities for obliteration of the cavity using various pedicled muscle grafts, in comparison with the endaural approach. Obliteration in an endaural approach is usually carried out with cartilage or bone (chips or paté) or with free muscle grafts (Table **8**), although a small pedicled temporalis muscle flap can be raised. The opportunities for creating an open cavity are the same in the retroauricular approach and the endaural approach. In both approaches, various skin flaps can be created, and the external auditory meatus can be widened equally in both approaches. Repneumatization and rebuilding an attic in order to ventilate the attic or the antrum can also be achieved with both approaches. Harvesting the reconstruction and obliteration materials, i. e., a large piece of fascia, a large piece of cortical bone, and larger quantities of bone

Table **8** Approaches and routes in canal wall–down mastoidectomy


Retroauricular
Transcortical route
Transmeatal route
Outside-in technique
Outside-in technique
Inside-out technique
Canal wall–down mastoidectomy
Open cavity
Obliteration: muscle, cartilage, bone
Repneumatization
Endaural
Transmeatal route
Transcortical route (rare)
Outside-in technique
Inside-out technique
Outside-in technique
Canal wall–down mastoidectomy
Open cavity
Obliteration: cartilage and bone
Repneumatization

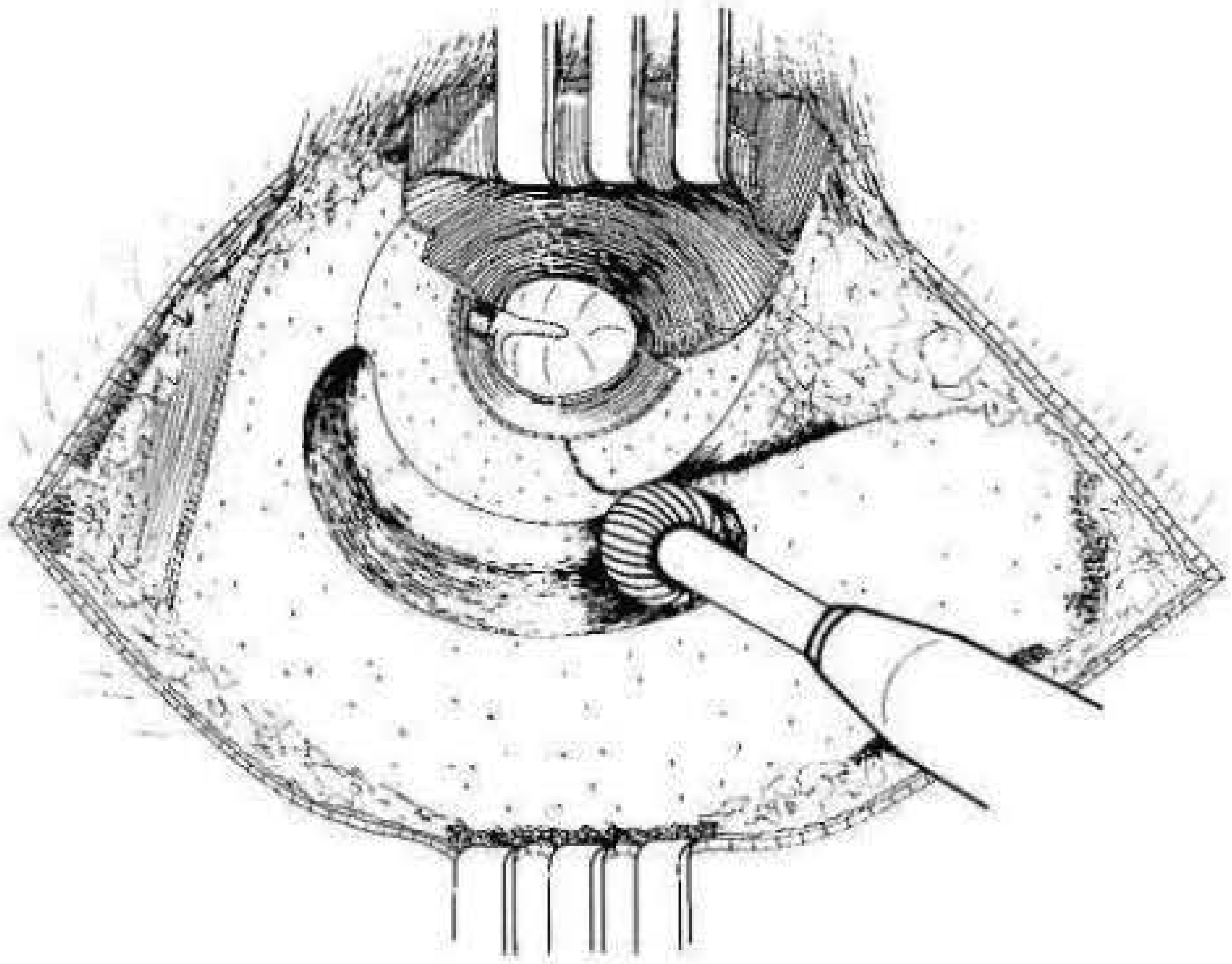


Fig. **615** **Transmeatal outside-in canal wall–down mastoidectomy in a retroauricular approach.** After a retroauricular flap incision (Vol. 1, Fig. 135–147) an anterior-based subcutis–muscle–periosteum flap is elevated, exposing the mastoid plane and temporal line, in the ear canal. A medial circumferential incision between the 12-o'clock and 6-o'clock positions and radial incisions at the 12-o'clock and 6-o'clock positions, with elevation of the posterior ear canal skin flap, are carried out. The posterior half of the ear canal and the mastoid plane are exposed, and drilling at the entrance to the ear canal using a large cutting burr is initiated

paste is easier in the retroauricular approach, and the cavity is therefore more often open after the endaural approach.

Transmeatal canal wall–down mastoidectomies can therefore be divided into: a) retroauricular operations and b) endaural ones.

The *retroauricular* operations are:

1. Outside-in mastoidectomy, starting at the suprameatal spine in a retroauricular approach.
2. Inside-out mastoidectomy, starting at the bony annulus in a retroauricular approach.

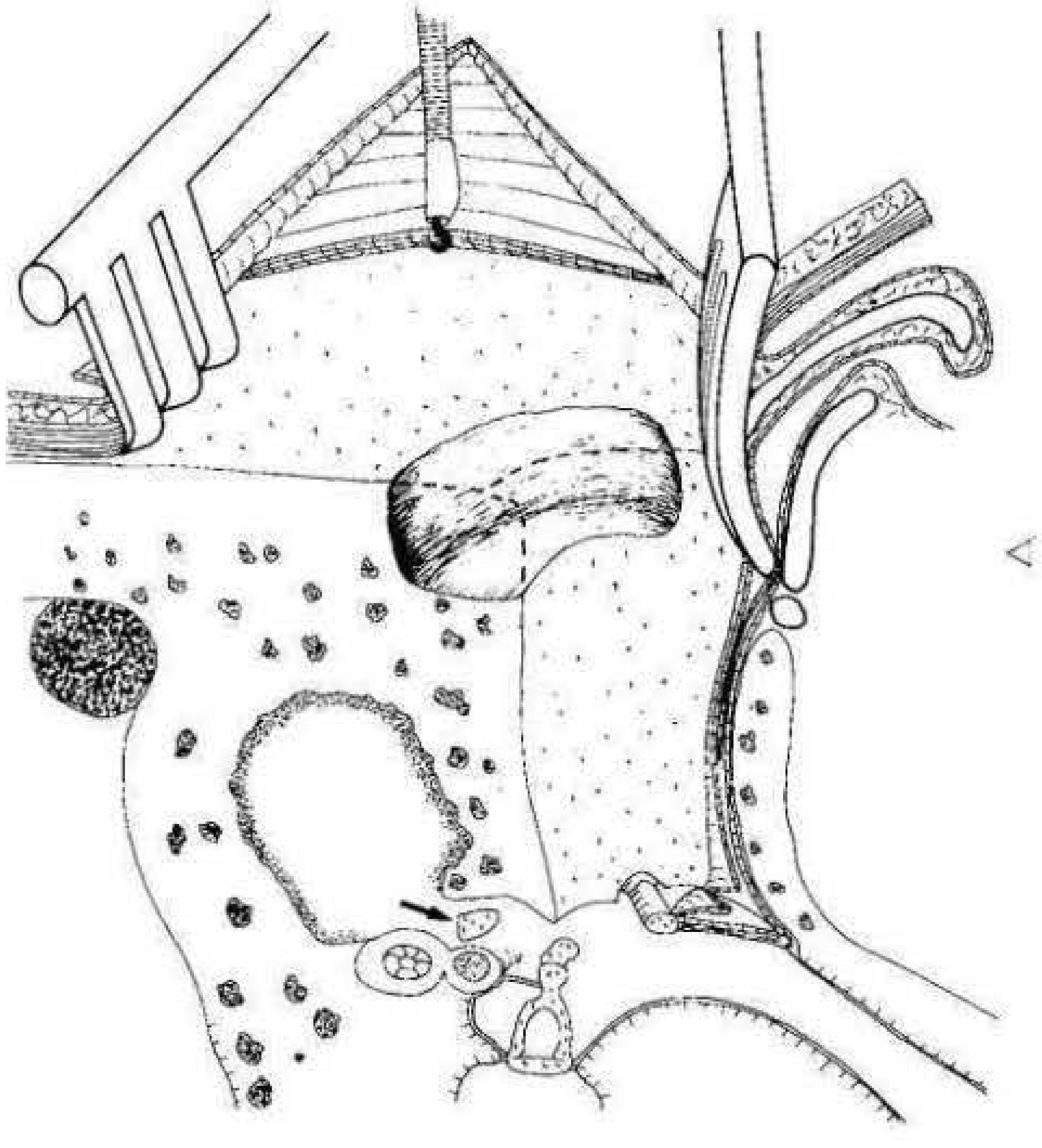
The *endaural* operations are:

1. Outside-in mastoidectomy, starting laterally by widening the ear canal in an endaural approach.
2. Inside-out mastoidectomy, starting at the annulus in an endaural approach.

Inside-out mastoidectomies are also termed "retrograde mastoidectomies."

Outside-in Transmeatal Canal Wall–Down Mastoidectomy

With a retroauricular approach, an anteriorly pedicled subcutis–muscle–periosteum flap is elevated and held in place using a self-retaining retractor. The canal skin is incised with a medial circumferential incision from the 12-o'clock, to the 6-o'clock positions and superior and inferior radial incisions at the 12-o'clock and 6-o'clock positions, respectively, allowing elevation of a large laterally based posterior ear canal skin flap (Körner flap), which is held in place with a selfretaining retractor. The mastoid plane and most of the ear canal are exposed (Fig. **615**), the temporal line is demarcated, and drilling is started using the largest cutting burr, first removing the suprameatal spine, and then the lateral part of the posterior bony ear canal wall (Fig. **616**). The drilling proceeds by continued



< Fig. **616** Side view with some perspective, illustrating a retroauricular approach and House selfretaining retractor with a protecting blade placed in the anterior part of the ear canal, protecting the posterior meatal skin flap. In the tympanic cavity, the malleus handle with the anterior part of the drum, the stapes with the lenticular process, and the short process of the incus (arrow) are indicated, as well as the facial nerve and the lateral semicircular canal.

The initial drilling is started at the entrance to the bony ear canal wall. The dashed line indicates the original position of the entrance of the ear canal (also in the following side-view figures)

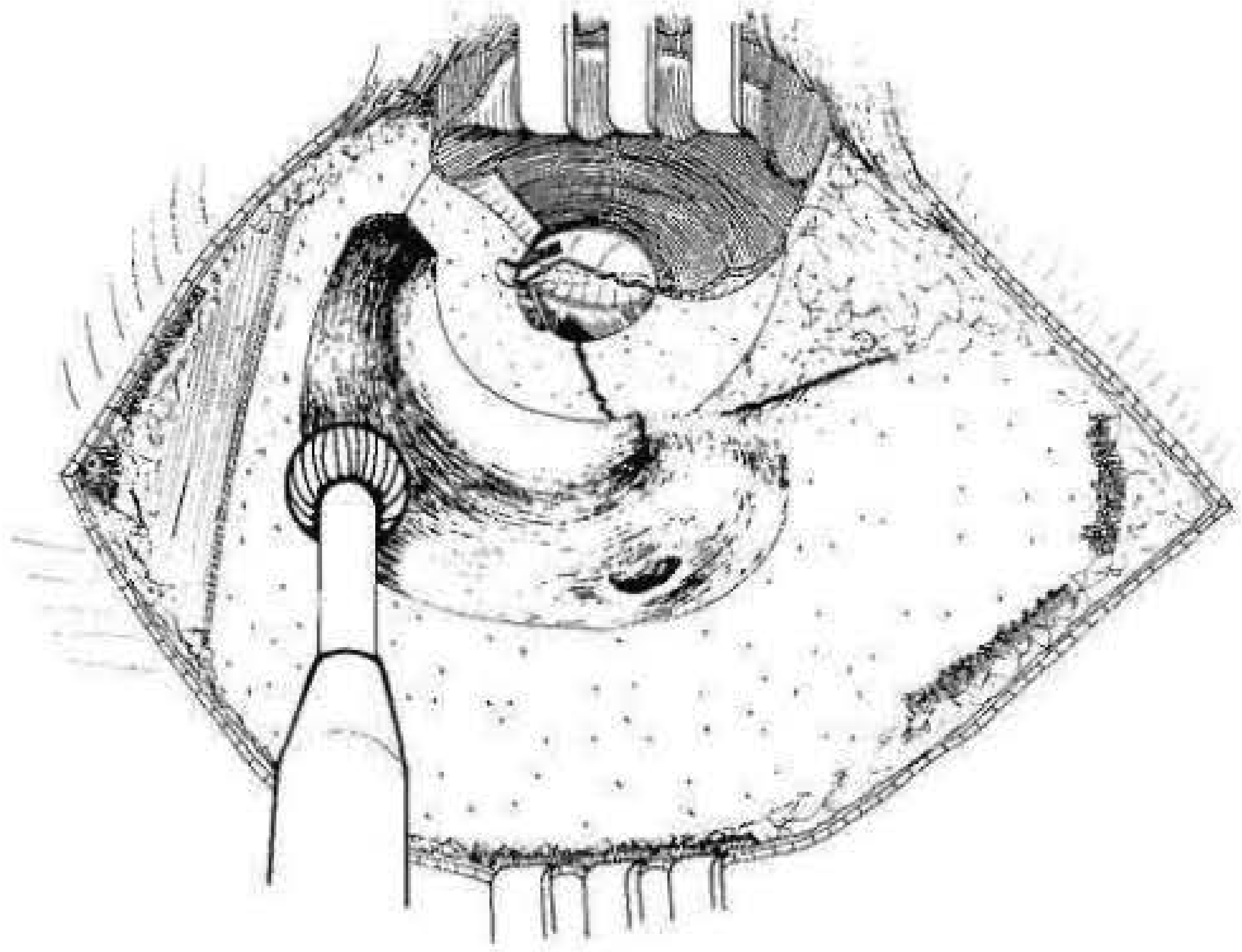


Fig. **617** Drilling continues along the mastoid tegmen, and more of the posterior bony ear canal is removed. Inferiorly, the very lateral part of the facial ridge is indicated. The antrum has not yet been reached, and the medial two-thirds of the ear canal are still intact

removal of the posterior bony ear canal wall between the 12-o'clock and 5-o'clock positions, and moves further posteriorly, along the middle fossa dural plate (Fig. **617**). Körner's septum has not yet been reached, and the antrum has not been opened (Fig. **618**). After further deeper drilling in a posterior direction along the middle fossa dural plate, Körner's septum is penetrated, and the antrum becomes visible through a small opening (Fig. **619**).

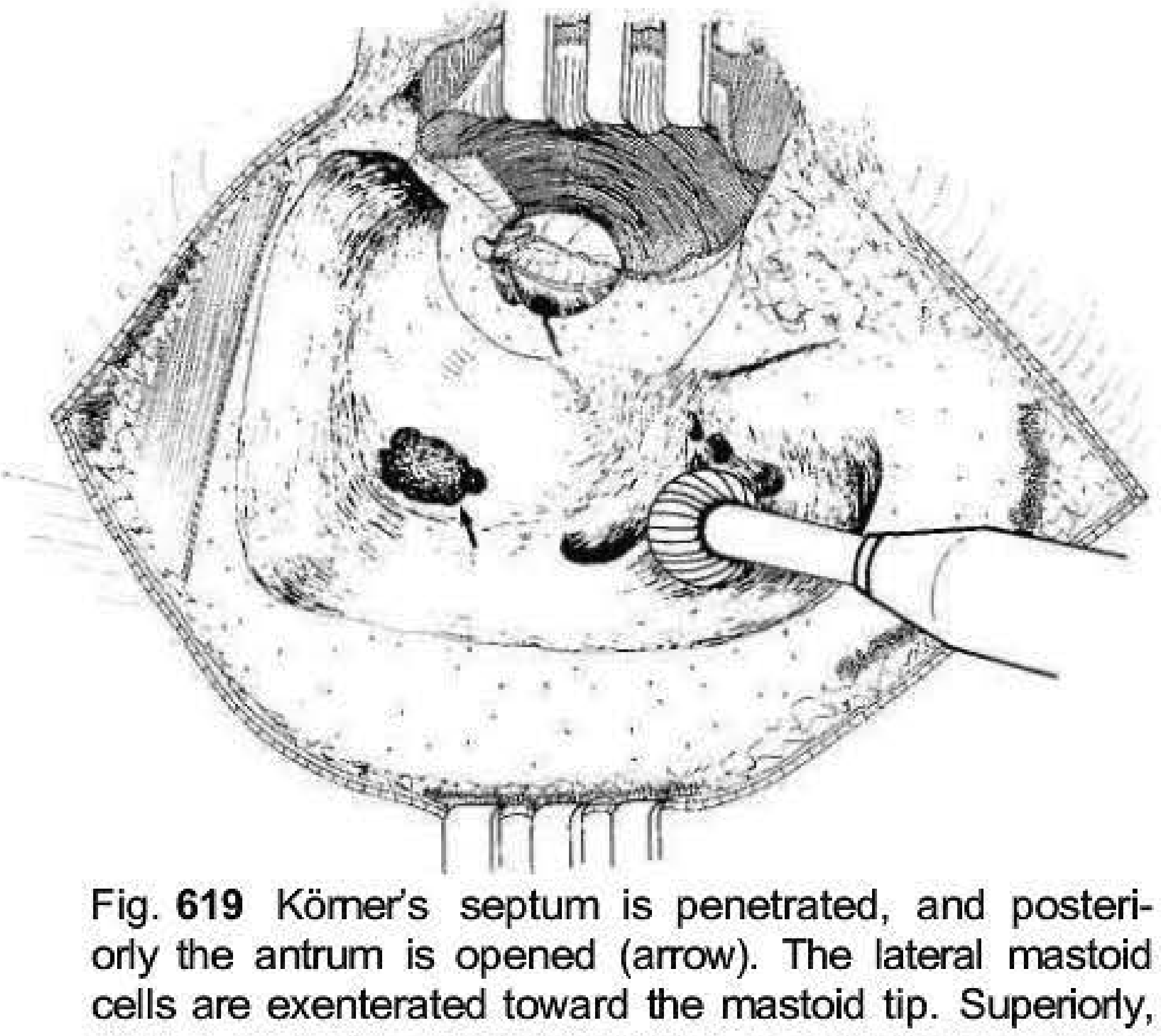


Fig. **619** Körner's septum is penetrated, and posteriorly the antrum is opened (arrow). The lateral mastoid cells are exenterated toward the mastoid tip. Superiorly, drilling along the mastoid tegmen is extended up to the middle fossa dural plate and the temporal line. The medial half of the posterior ear canal wall is still intact

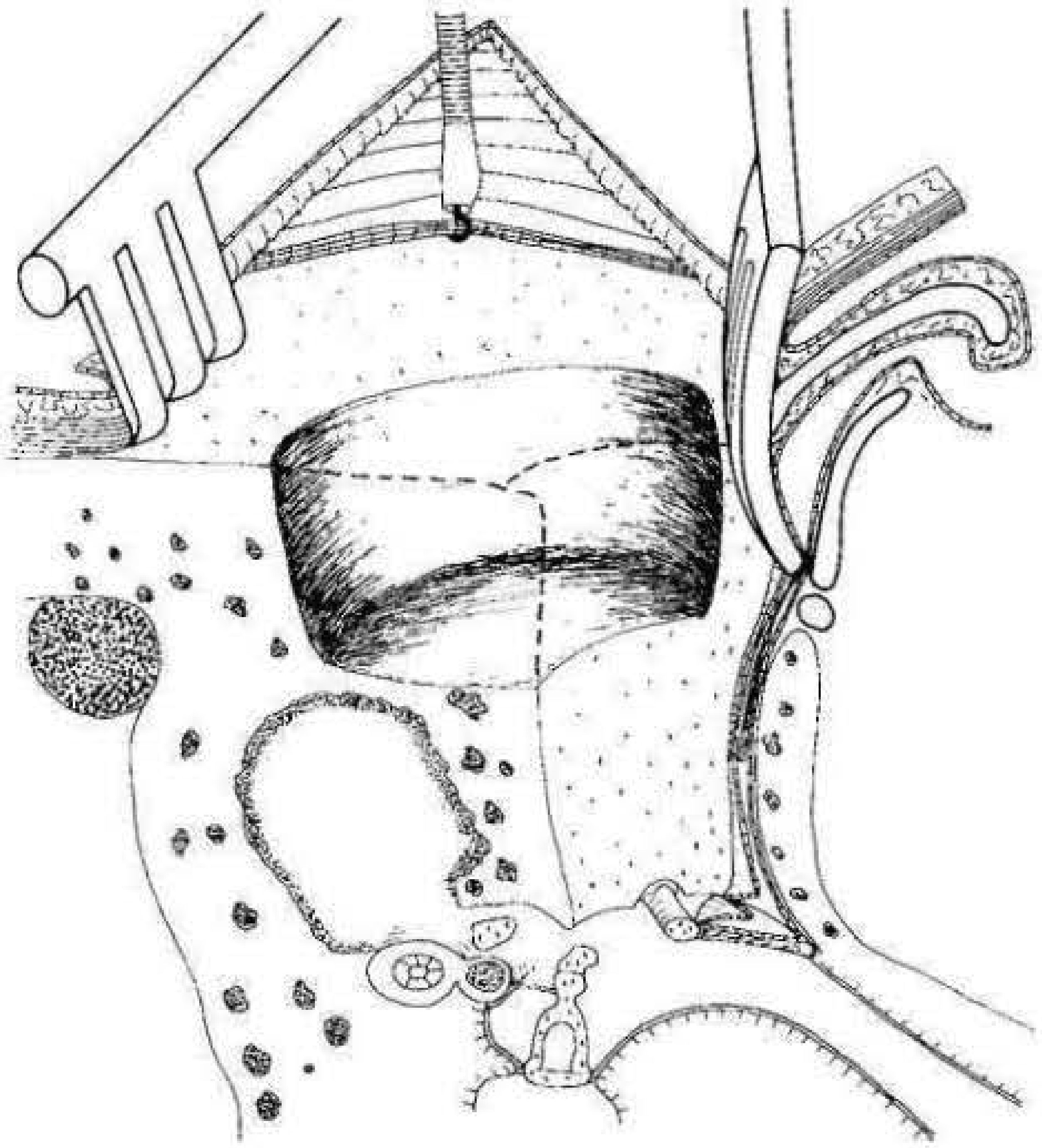


Fig. **618** Side view some perspective of the drilling, which has just reached the Körner's septum level. The antrum has not been opened yet. A posterior tympanotomy is performed, exposing the incudostapedial joint

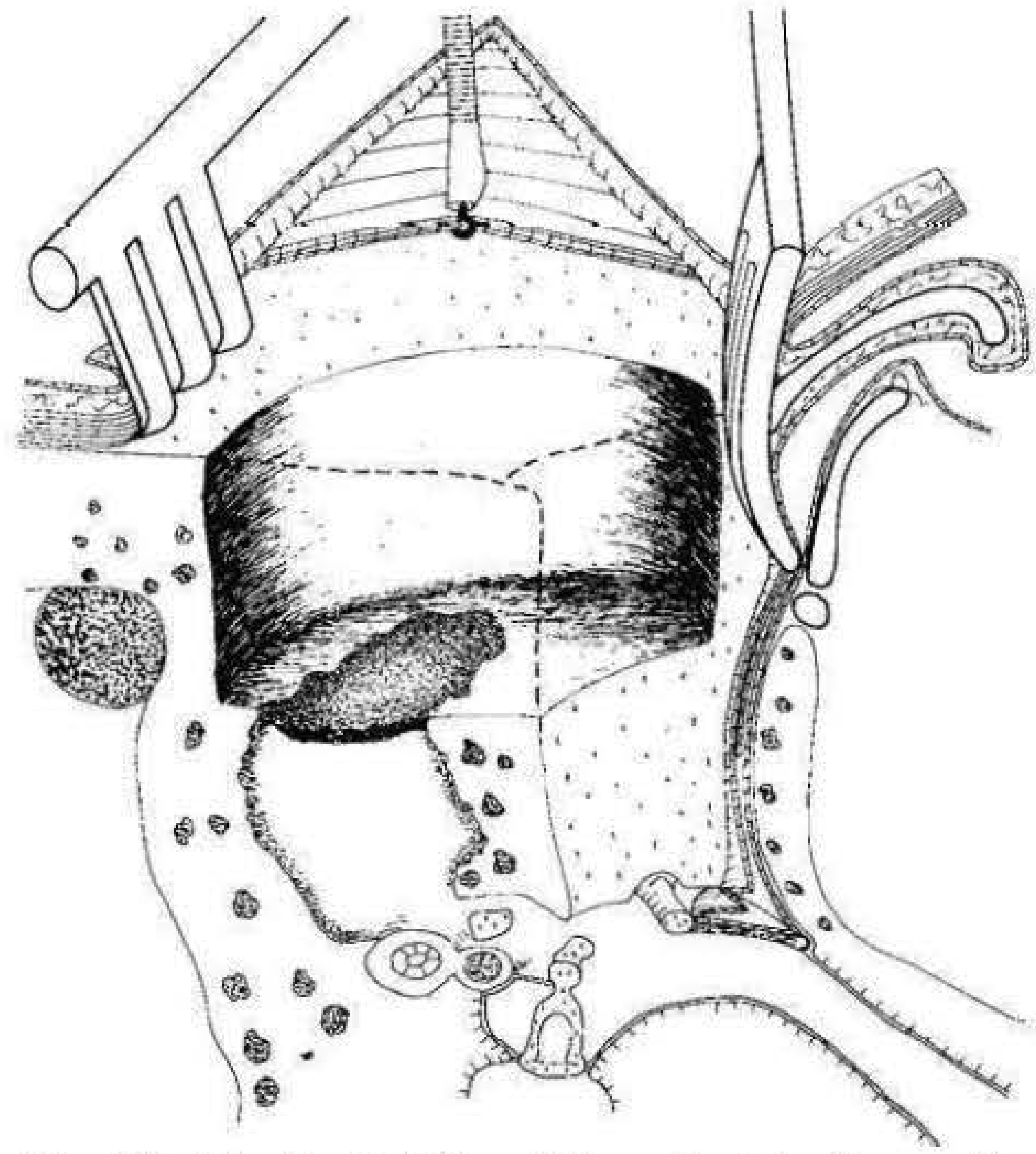


Fig. **620** The level of the drilling, illustrated in a side view of the mastoid process with some perspective. The antrum has been opened. The dashed line indicates the original entrance of the ear canal. The medial half of the bony ear canal wall is still intact

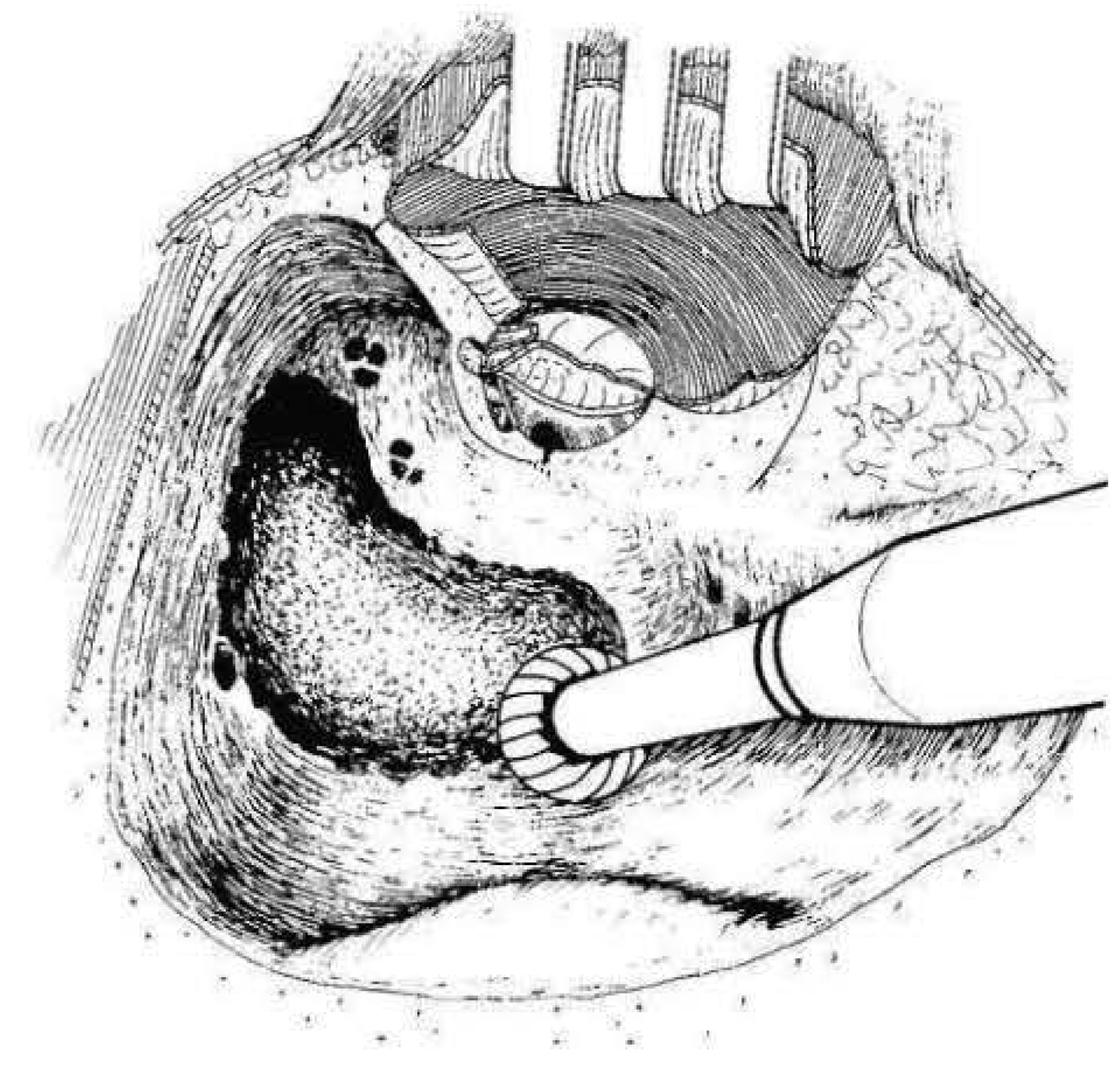


Fig. **621** The antrum has been widely opened, and the cavity walls have been smoothed. Posteriorly, the prominence of the lateral sinus and a smoothed posterior fossa dural bony plate are seen, and medially, the anterior attic. The ossicular chain and the lateral semicircular canal are conceded by bone and not visible

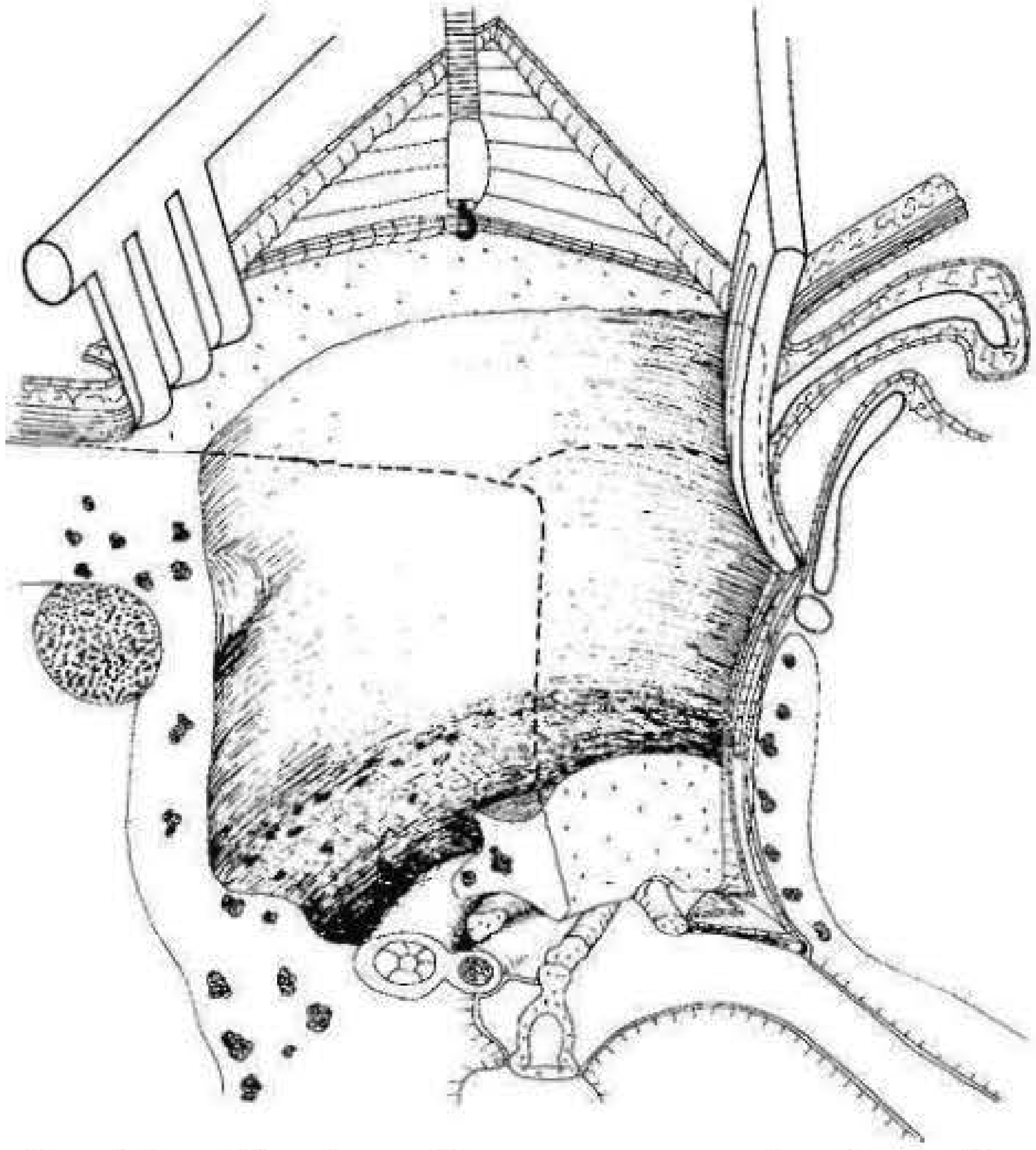


Fig. **622** Side view with some perspective illustrating the level of the drilling in transmeatal outside-in canal wall–down mastoidectomy. The mastoid tegmen is smoothed, and the antrum has been completely opened. The posterior fossa dural plate is smoothed, but more or less the medial quarter of the ear canal wall is still intact, covering the incus and the lateral semicircular canal

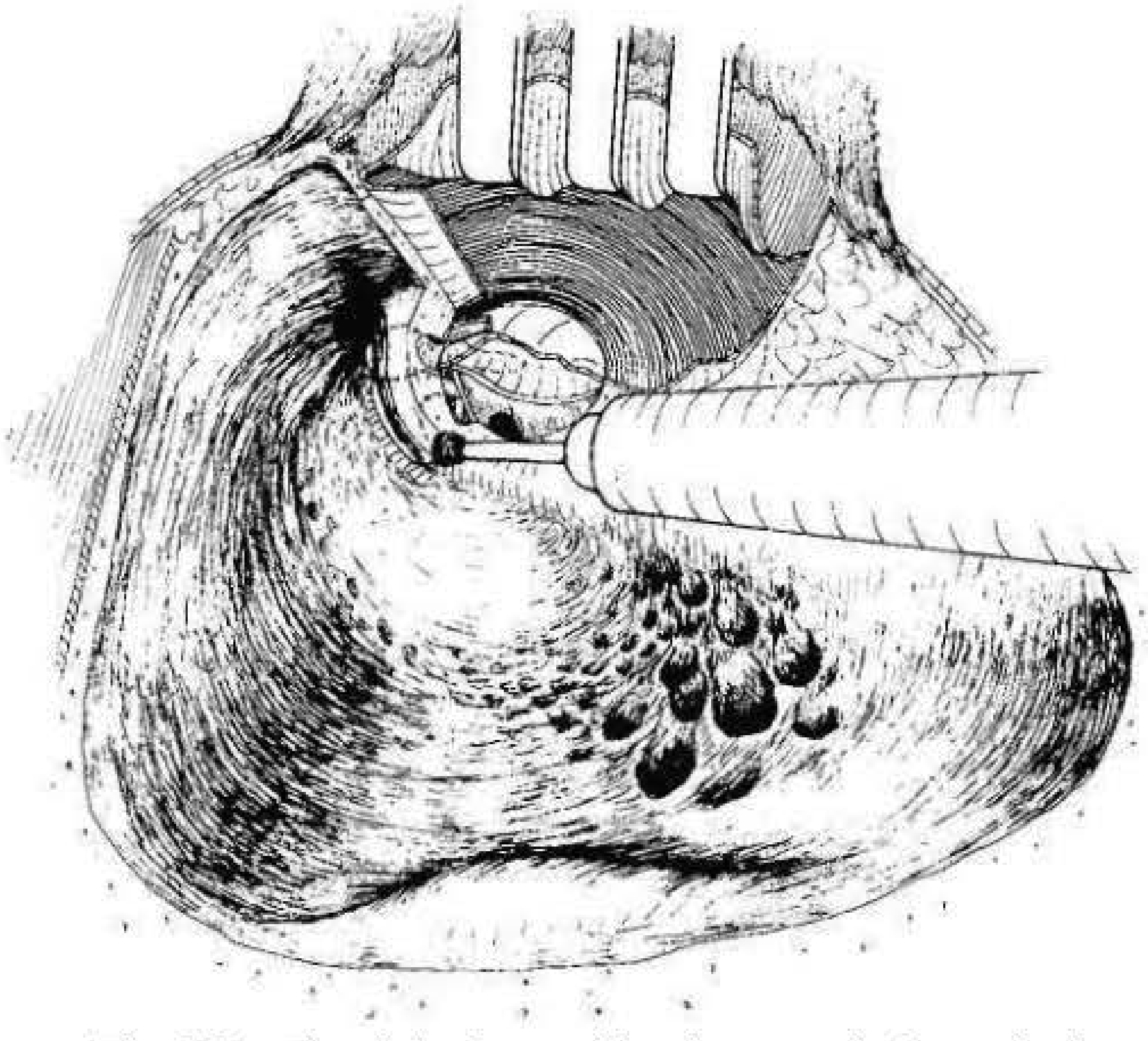


Fig. **623** The lateral semicircular canal, incus body, and malleus head are only partly exposed, but still some 2 mm of the ear canal remains to be removed. The tegmen antri is smoothed, and the facial ridge is gradually lowered to achieve removal of the ear canal wall

The lateral mastoid air cells are exenterated toward the mastoid tip. The depth of the drilling is easy to determine because of the constantly visible surface of the ear canal, allowing assessment of the distance to the bony annulus (Fig. **620**). The opening to the antrum is gradually enlarged, and Körner's septum is removed until the antrum has been completely opened (Fig. **621**). The bony overhangs over the antrum are removed, the middle fossa and posterior fossa dural plates polished, and the ear canal wall is further lowered (Fig. **622**).

Drilling continues posteriorly along the middle fossa dural plate, smoothing it and exenterating the cells from the sinodural anlge (Fig. **623**). The ear canal is further lowered, and a careful inspection of the lateral semicircular canal and ossicular chain, which now becomes visible, is made (Fig. **624**). Further lowering of the bony ear canal, using a diamond burr, exposes more and more of the ossicular chain (Fig. **625**). The anterior attic is reached by further lowering of the bridge, and the tensor tympani fold (Figs. **92–94**) is penetrated using a curved

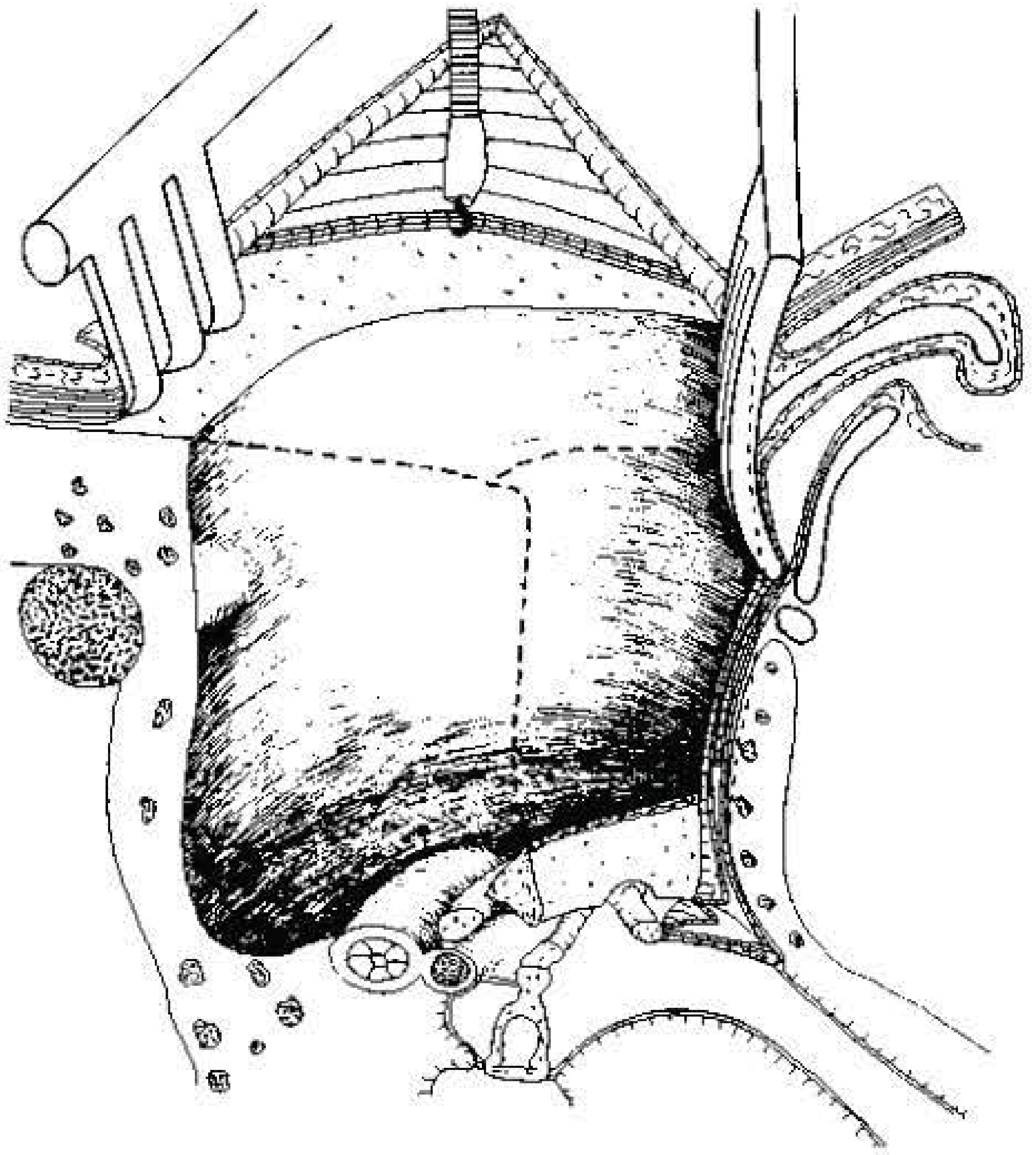


Fig. **624** Side view of the level of the drilling, illustrating gradual removal of the ear canal wall, which has been lowered to 1.5 mm

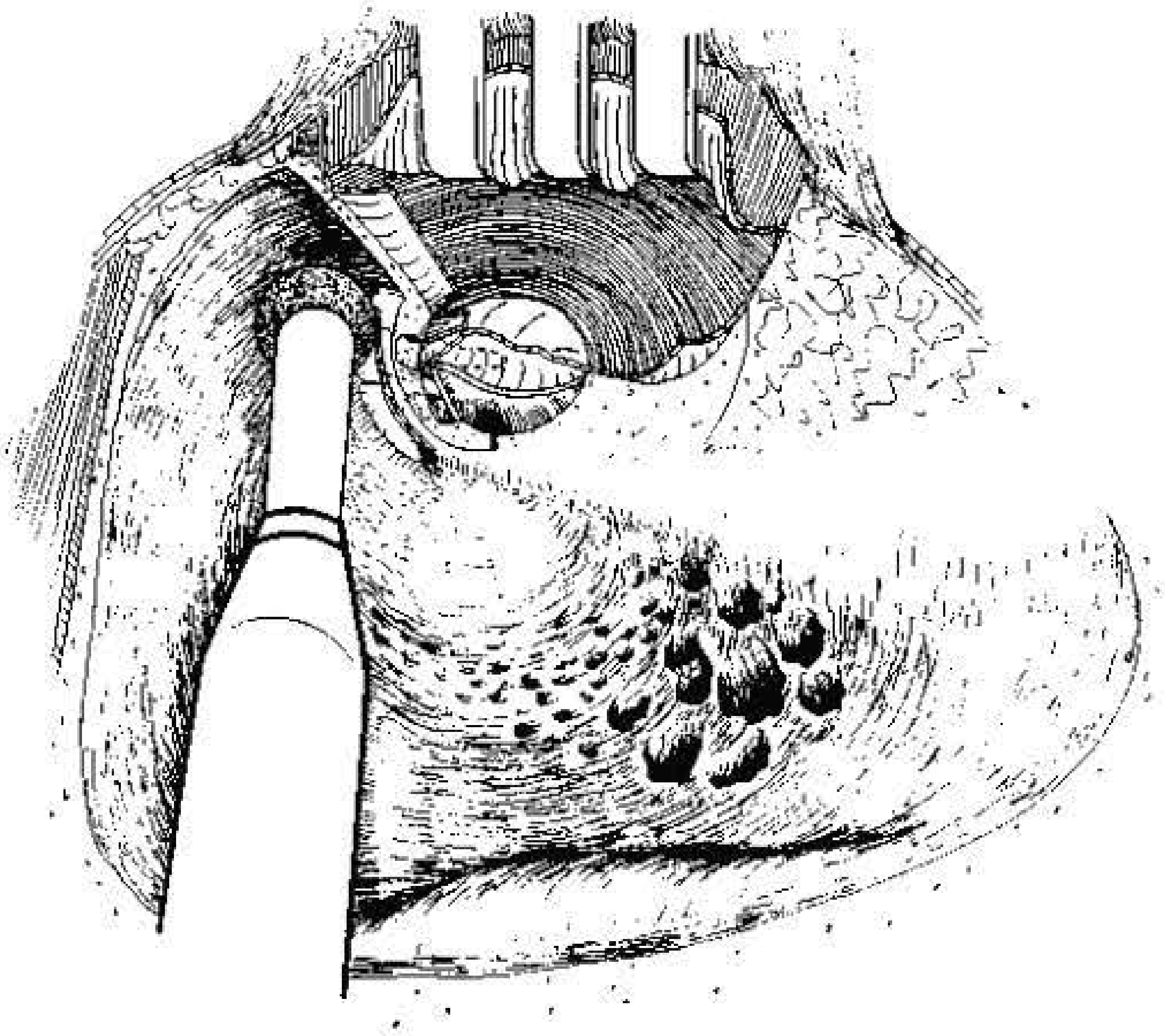


Fig. **625** Further removal of the ear canal wall and exposure of the malleus head and incus body, continuing with drilling toward the anterior attic

rugine (Fig. **626**). Further drilling leads to maximal thinning of the bony bridge. The facial ridge is lowered, and all the walls of the cavity are polished (Figs. **627, 628**).

In cases with extensive pneumatization, any large mastoid tip cells have to be removed (Fig. **629**), resulting in a large cavity (Fig. **630**). In cases with extensive pneumatization, the advantage of the retroauricular approach compared to the endaural approach is therefore evident. Drilling toward the mastoid tip is difficult in an endaural approach, but easy in a retroauricular approach (Fig. **629**).

Of course, canal wall–down mastoidectomy usually results in removal of the bridge, and the results are exactly the same as those illustrated for transcortical canal wall–down mastoidectomy, leading to the following situations:

1. Preservation of the intact ossicular chain, without the bridge but with a relatively high facial ridge (Figs. **584, 585**).

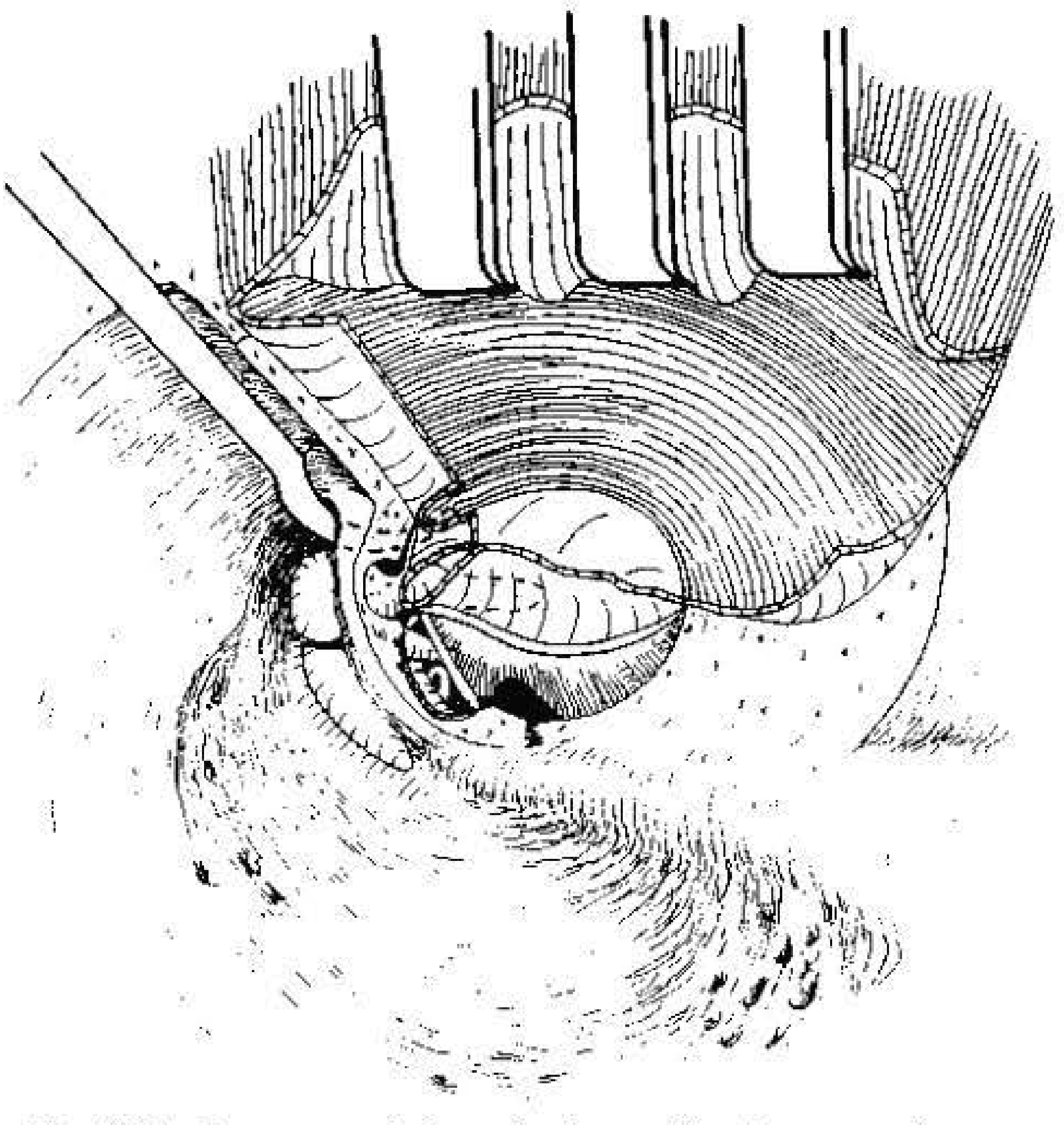


Fig. **626** **Transmeatal anterior atticotympanotomy.** With a curved rugine, the tensor tympani fold is penetrated, the bony bridge is further thinned and the facial ridge is lowered

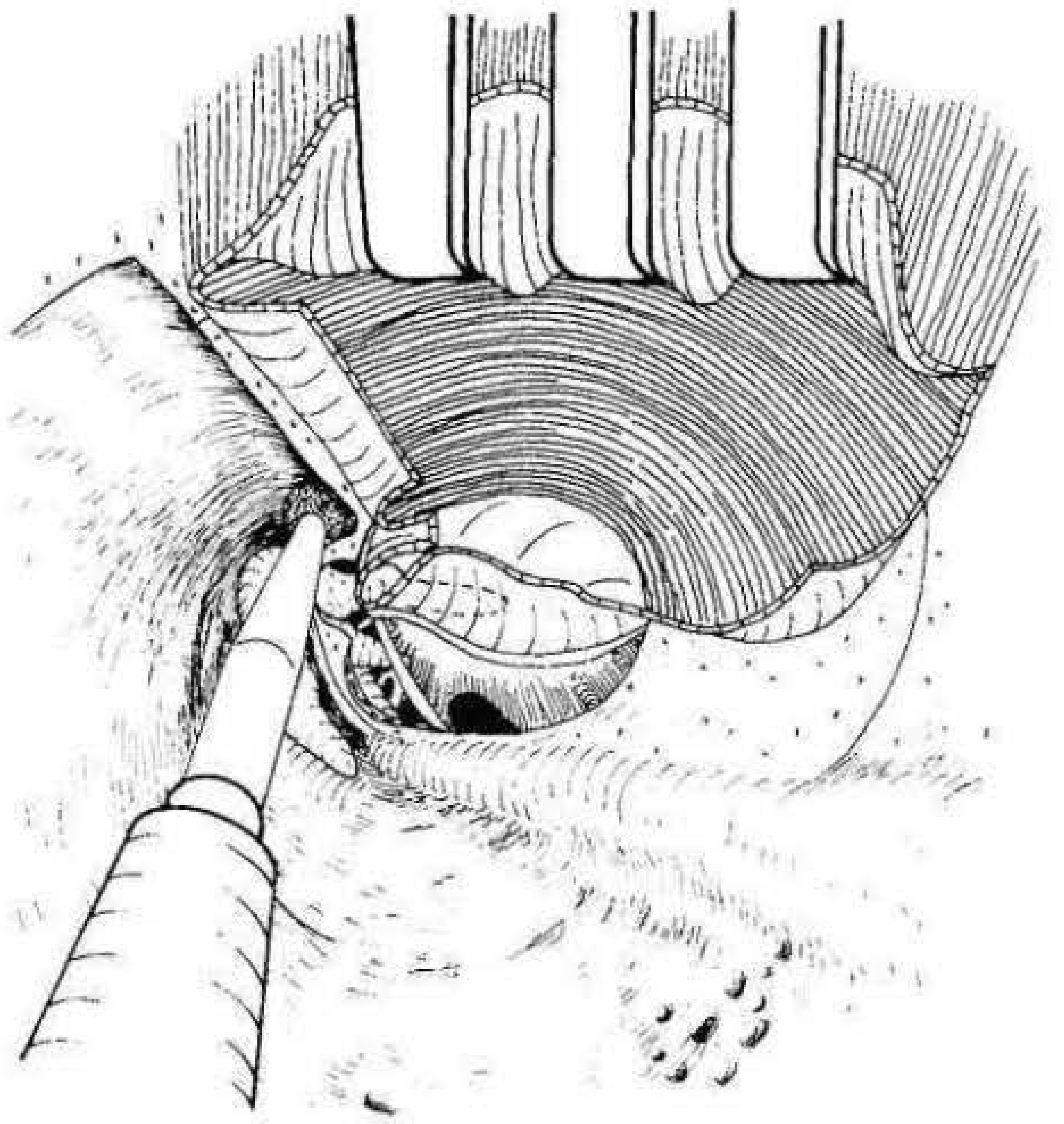


Fig. **627** Using a diamond burr, the anterior bony plate is removed and the anterior attic further exposed

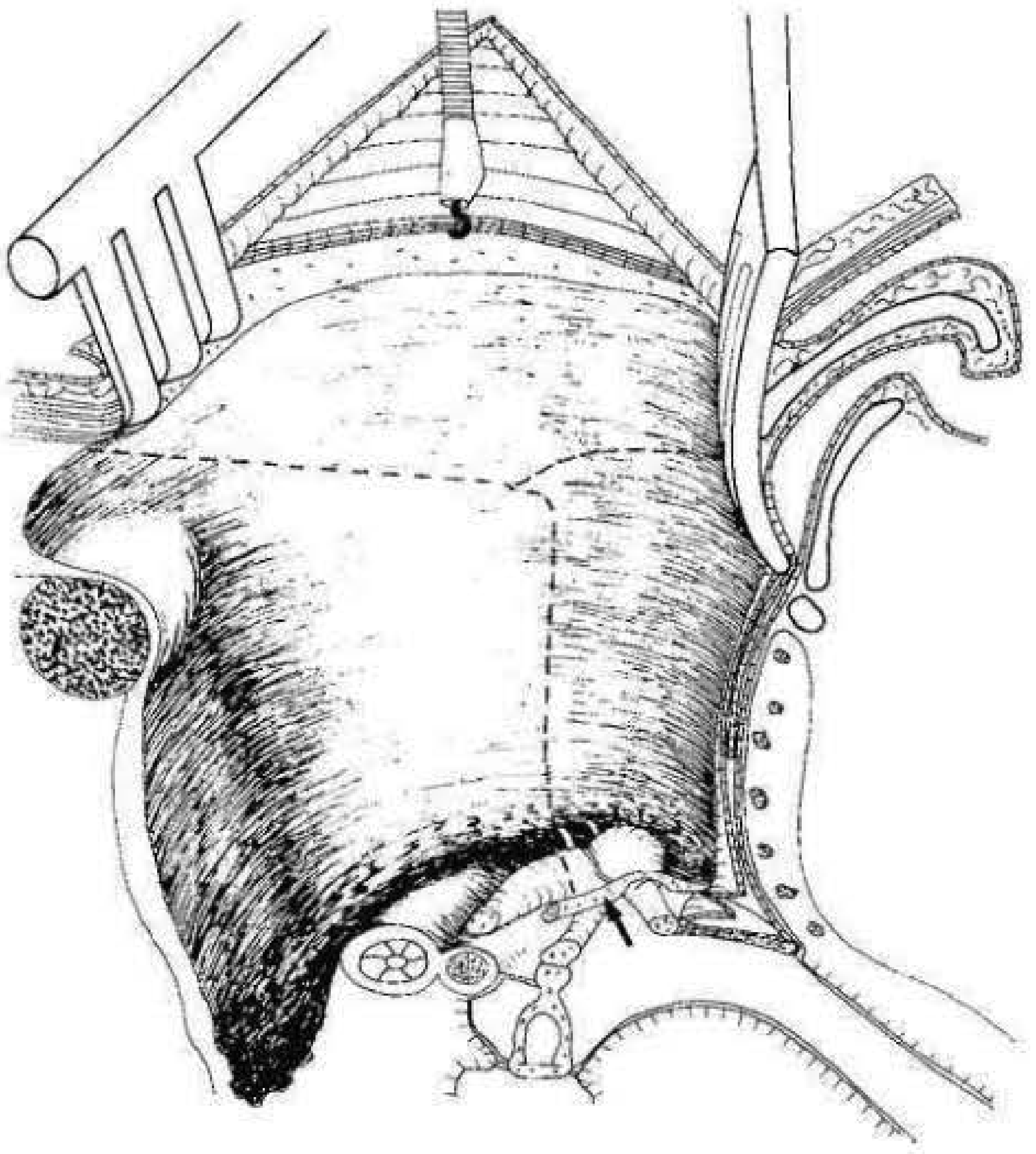


Fig. **628** Side view of the cavity in transmeatal canal wall–down mastoidectomy with preservation of the bridge. The bony bridge is thin (arrow), and the cavity walls have been smoothed

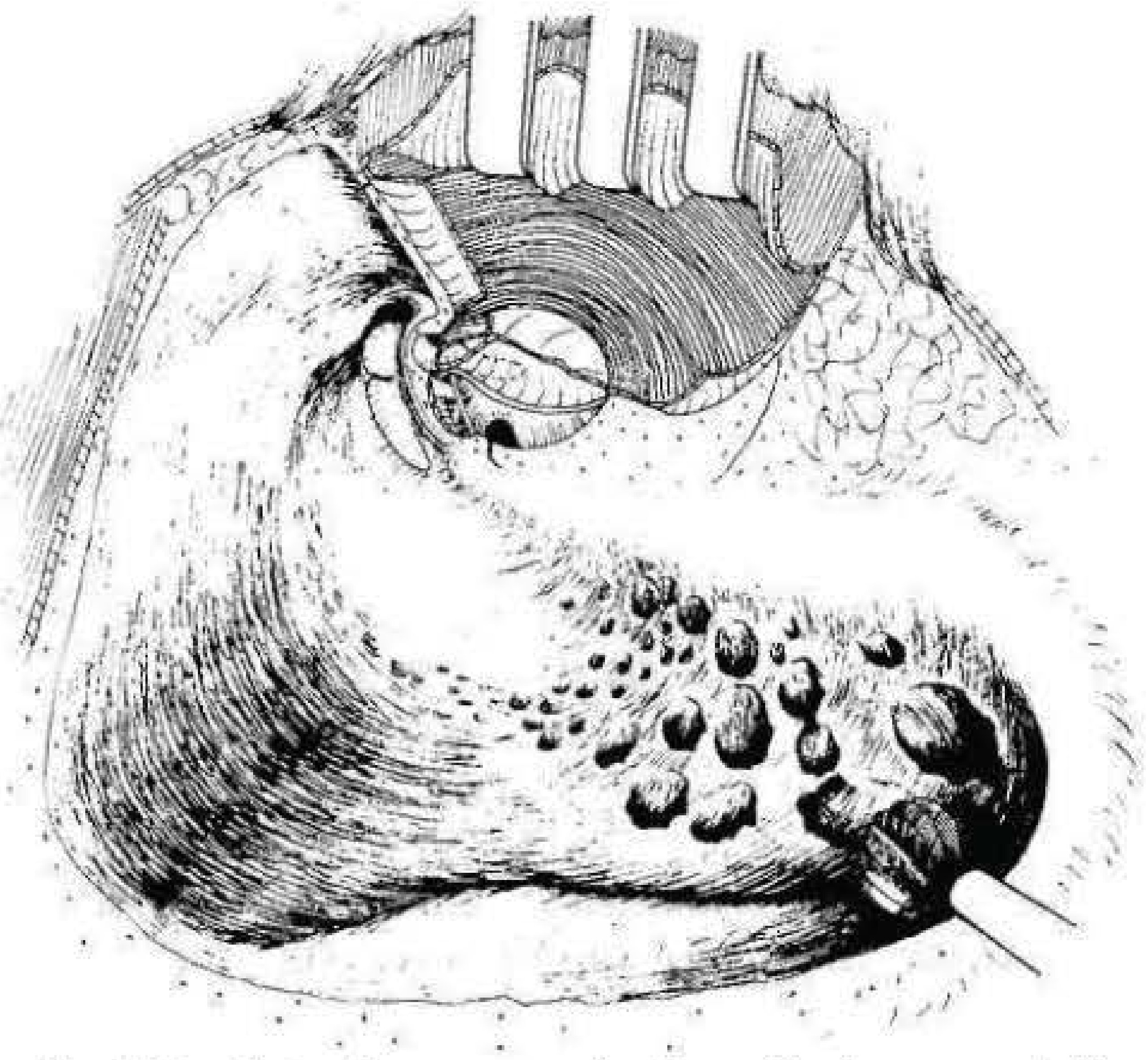


Fig. **629** Extensive pneumatization with large mastoid tip cells being exenterated using **a** large cutting burr

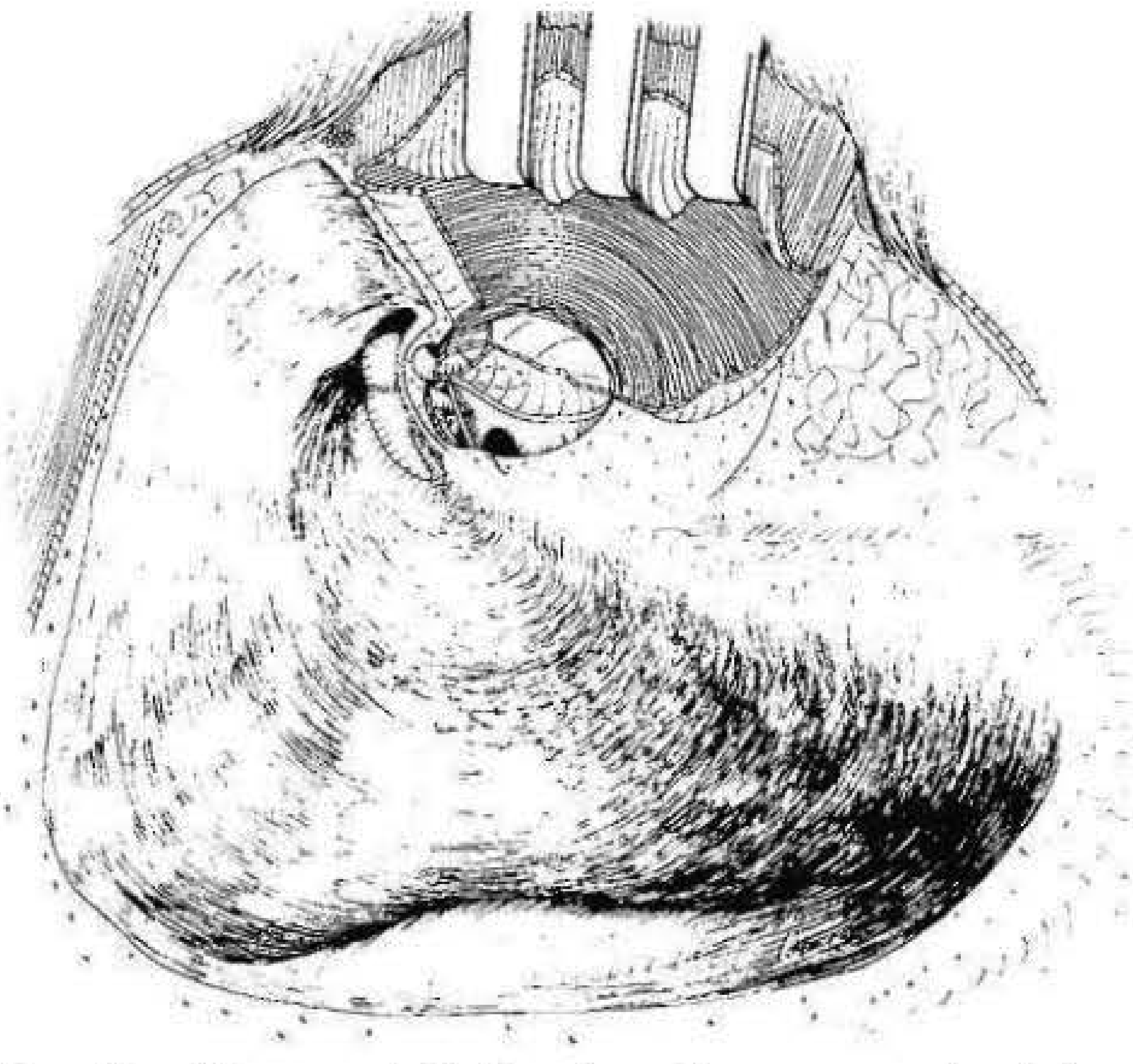


Fig. **630** The mastoid tip air cells are exenterated, resulting in a relatively large cavity

2. Preservation of the intact ossicular chain and a low facial ridge (Figs. **586, 587**).
3. Removal of the incus, but preservation of the malleus and a low facial ridge (Figs. **588, 589**).
4. Resection of the malleus head and removal of the incus, with lowering of the facial ridge (Figs. **590, 591**).
5. Removal of the entire malleus and incus, usually accompanied by an absent stapedial arch (Fig. **631**) and its reconstruction with an L-shaped columella and fascial graft (Fig. **632**).

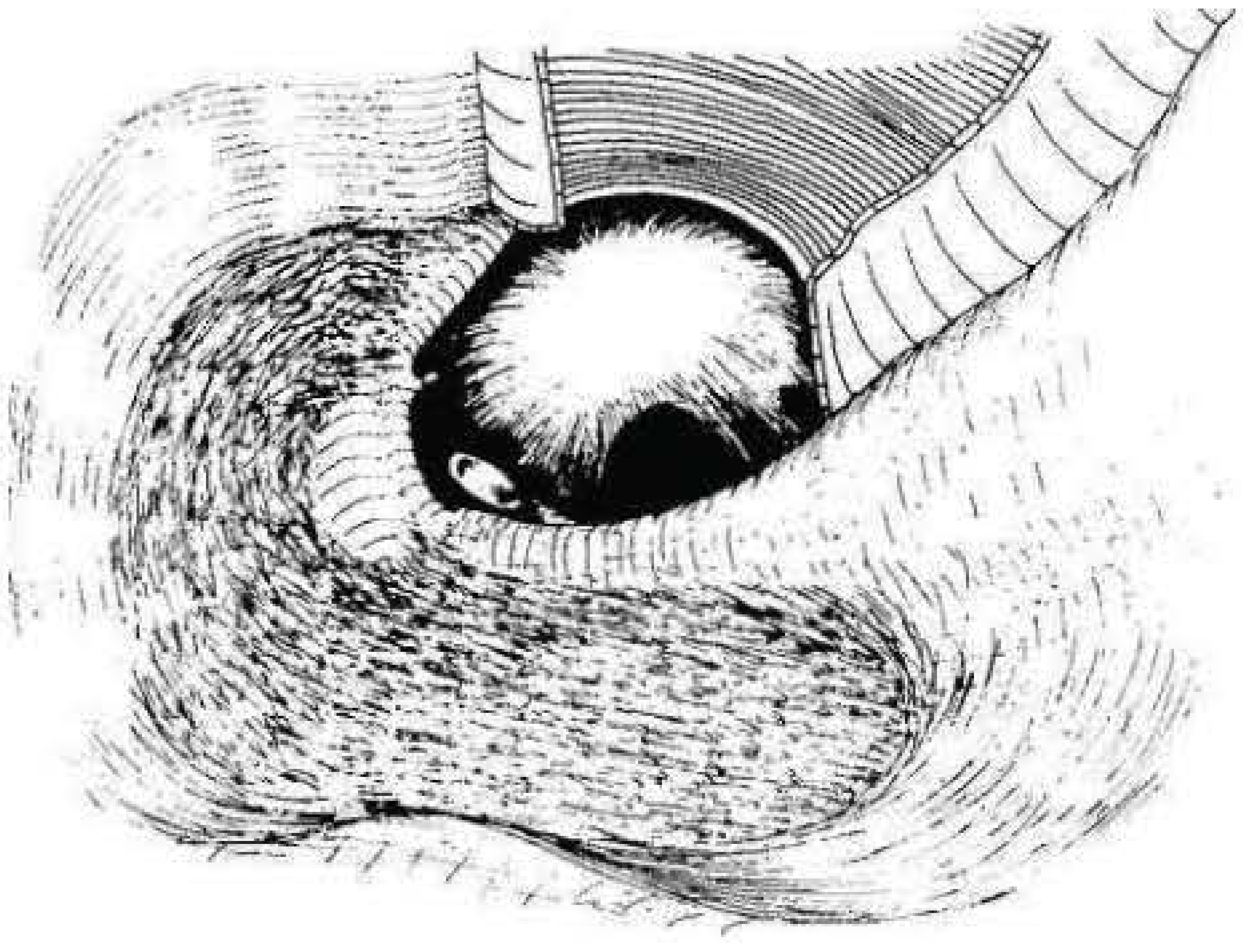


Fig. 631 **Canal wall–down mastoidectomy leaving only the fibrous annulus** of the drum and a mobile footplate

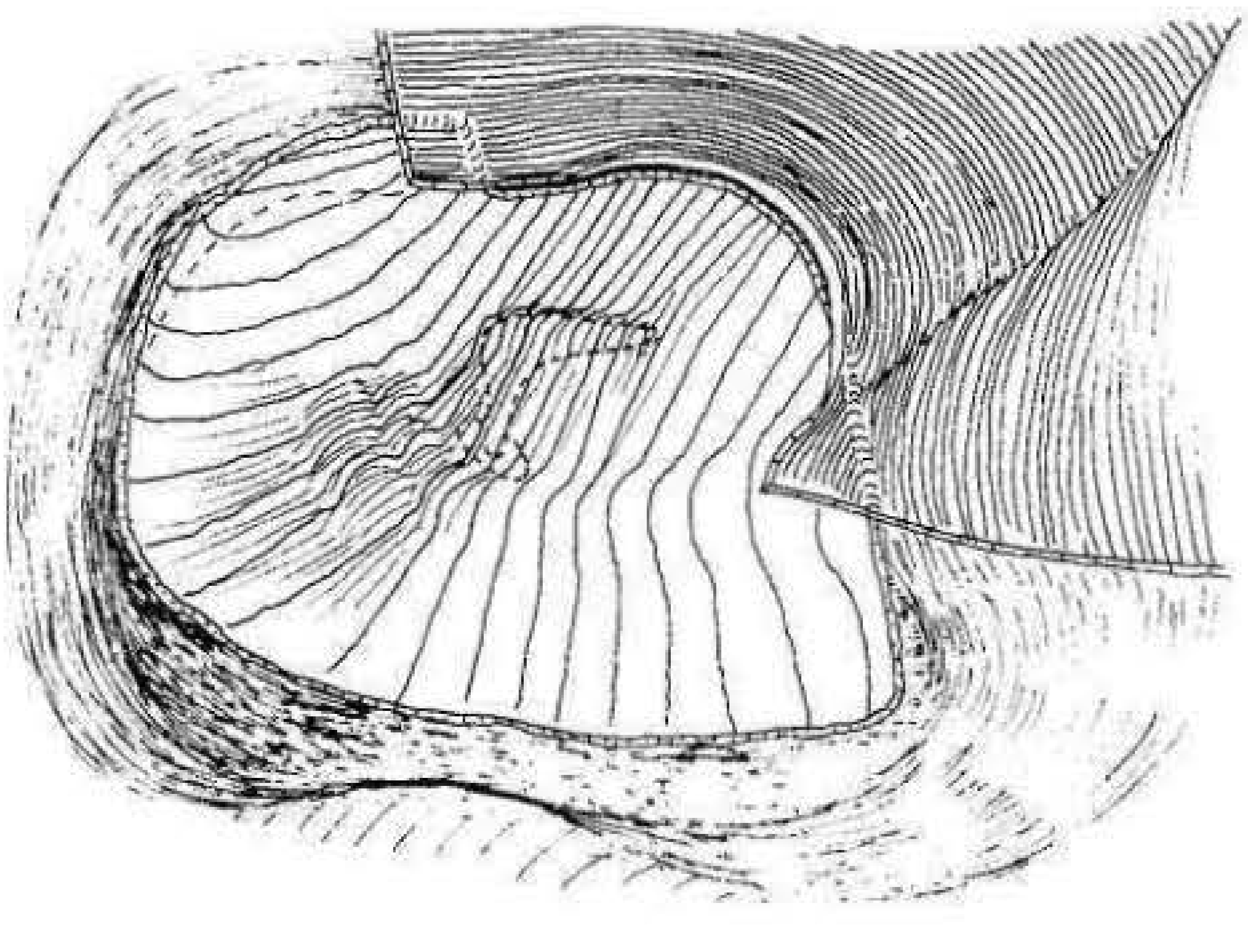


Fig. 632 **Reconstruction of the tympanic cavity with an L-shaped columella** and fascia placed as an underlay graft under the fibrous annulus onto the medial walls of the attic, aditus ad antrum, and facial ridge

Partial preservation of the bridge may also result from a transmeatal canal wall–down mastoidectomy in the same way as in a transcortical canal wall–down mastoidectomy, e. g., preservation of the anterior and posterior parts of a spontaneously eroded bridge. Such situations appear in cases with:

1. An intact ossicular chain and a small posterior atticotympanotomy (Figs. **592, 593**).
2. A missing incus with a small posterior atticotympanotomy and partly preserved bridge (Figs. **594, 595**).
3. A missing malleus head and incus with partial preservation of the posterior part of the bridge (Figs. **596, 597**).

The goal of preservation of the bridge in cases with a missing incus and malleus head is essentially to maintain the height of the tympanic cavity, rather than to reventilate the attic. In cases with an intact ossicular chain and partial preservation of the bridge, the attic is reventilated.

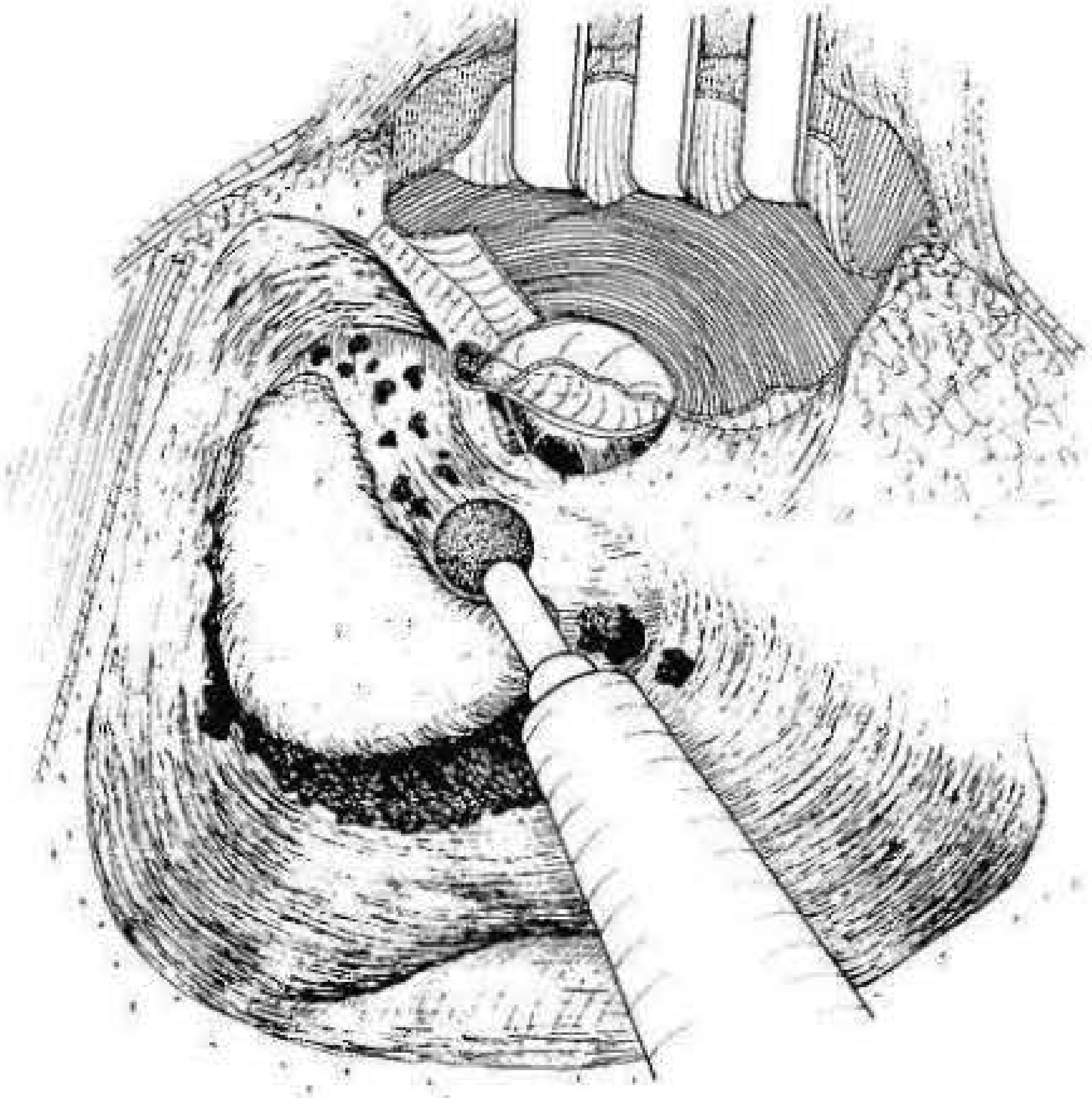


Fig. 633 **Removal of an attic cholesteatoma by transmeatal canal wall–down mastoidectomy using the outside-in route.** After the antrum has been opened and the lateral half of the bony ear canal, has been removed, a cholesteatoma is exposed

Removal of Attic Cholesteatoma in Transmeatal Outside-In Mastoidectomy

After removal of Körner's septum, a cholesteatoma may be found in the antrum (Fig. **633**). With continuous drilling of the bony ear canal wall and removal of the bridge, the cholesteatoma is gradually totally exposed (Fig. **634**). The posterior and anterior butresses are removed using a diamond burr, and the cholesteatoma sac is elevated from the antrum walls. After the extent of the cholesteatoma has been demarcated, the sac is opened and the cholesteatoma mass is removed using a thick suction tube, debulking the cholesteatoma. Elevation of the cholesteatoma matrix can take place, and it is

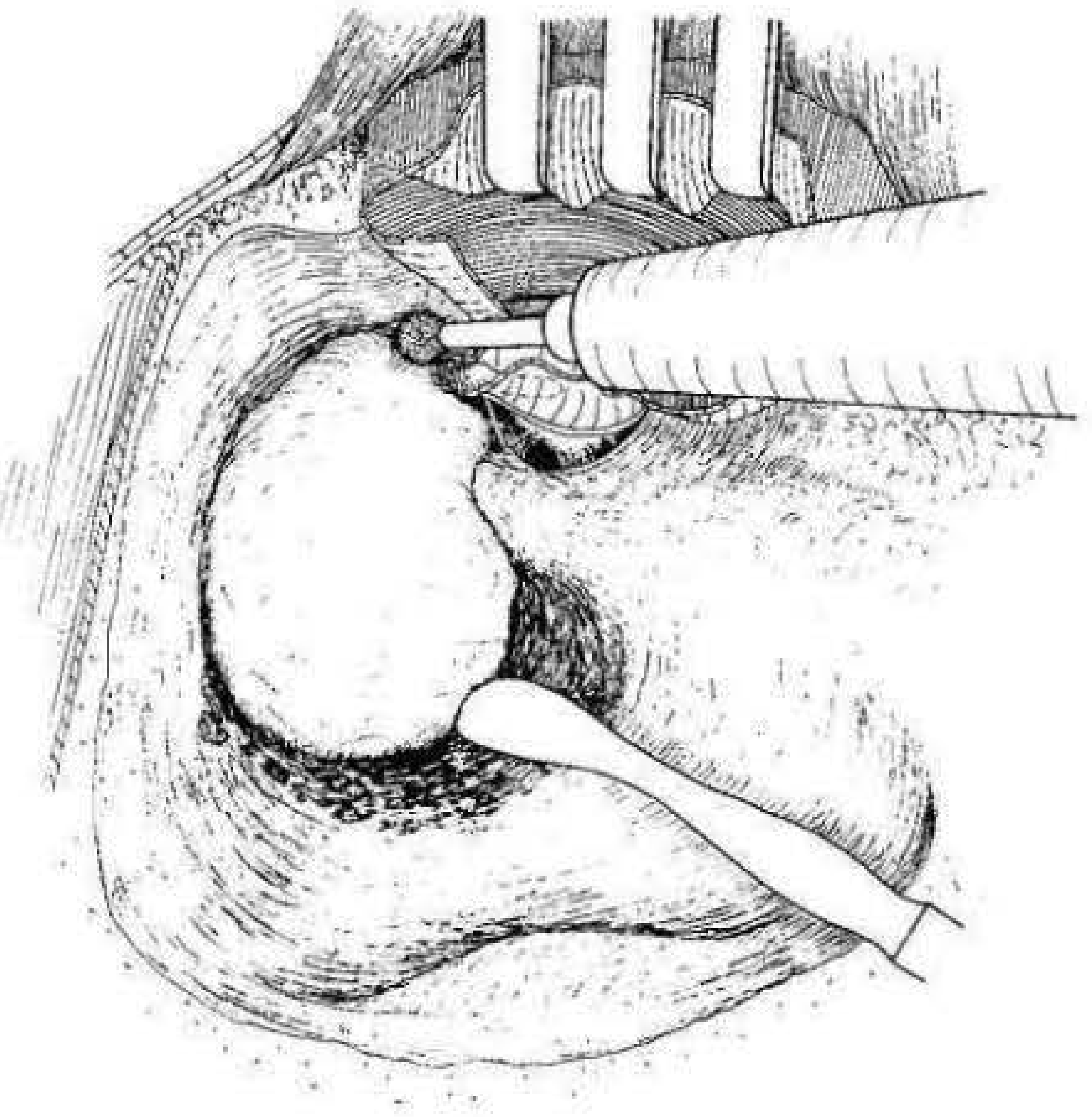


Fig. **634** The ear canal wall, including the bridge, is removed, exposing all the cholesteatoma. The anterior buttress is removed using a diamond burr, and the cholesteatoma sac is elevated with a rugine. The posterior buttress is still present, and the lenticular process with the remnant of the long process of the incus is visible

pushed gently toward the attic using a cottonoid ball (Fig. **635**). The cholesteatoma has usually completely surrounded and severely eroded the incus body and the malleus head. It is elevated from the remnant of the long process of the incus (Fig. **636**). The anterior attic is cleared of cholesteatoma, and the neck of the malleus cut using a punch (Fig. **637**). The cholesteatoma remnant, together with the remnant of the incus body and malleus head, is elevated and removed. This type of cholesteatoma removal is the most efficient, but the malleus neck and anterior ligament have to be cleaned before resection of the malleus head.

Because the malleus head and incus body are removed, the superior and anterior attic wall needs to be drilled down as far as the level of the lateral semicircular canal and the facial nerve, leaving no bony overhangs (Fig. **638**).

Reconstruction of such ears is usually based on leaving an open attic and aditus ad antrum and placing the fascia as an underlay graft under the anterior part of the drum remnant, on the neck of the malleus and under the posterior part of the drum, resulting in the fascia covering the entire medial wall of the attic, or possibly even the antrum, as well as the facial ridge (Fig. **639**).

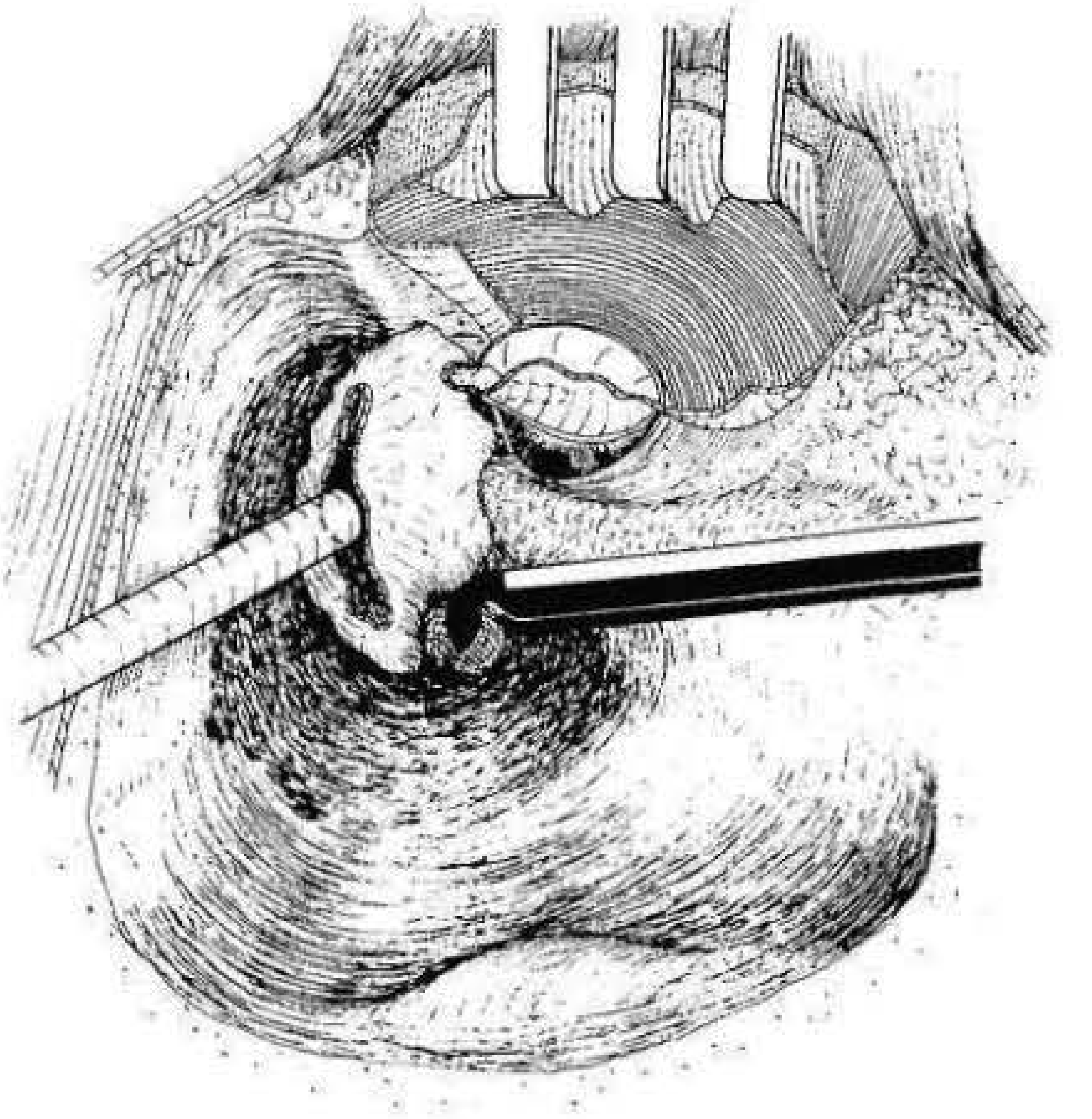


Fig. **635** The cholesteatoma sac is opened and debulked using a thick suction tube, and the cholesteatoma membrane is carefully elevated using a cottonoid ball, pushing the membrane toward the lateral semicircular canal

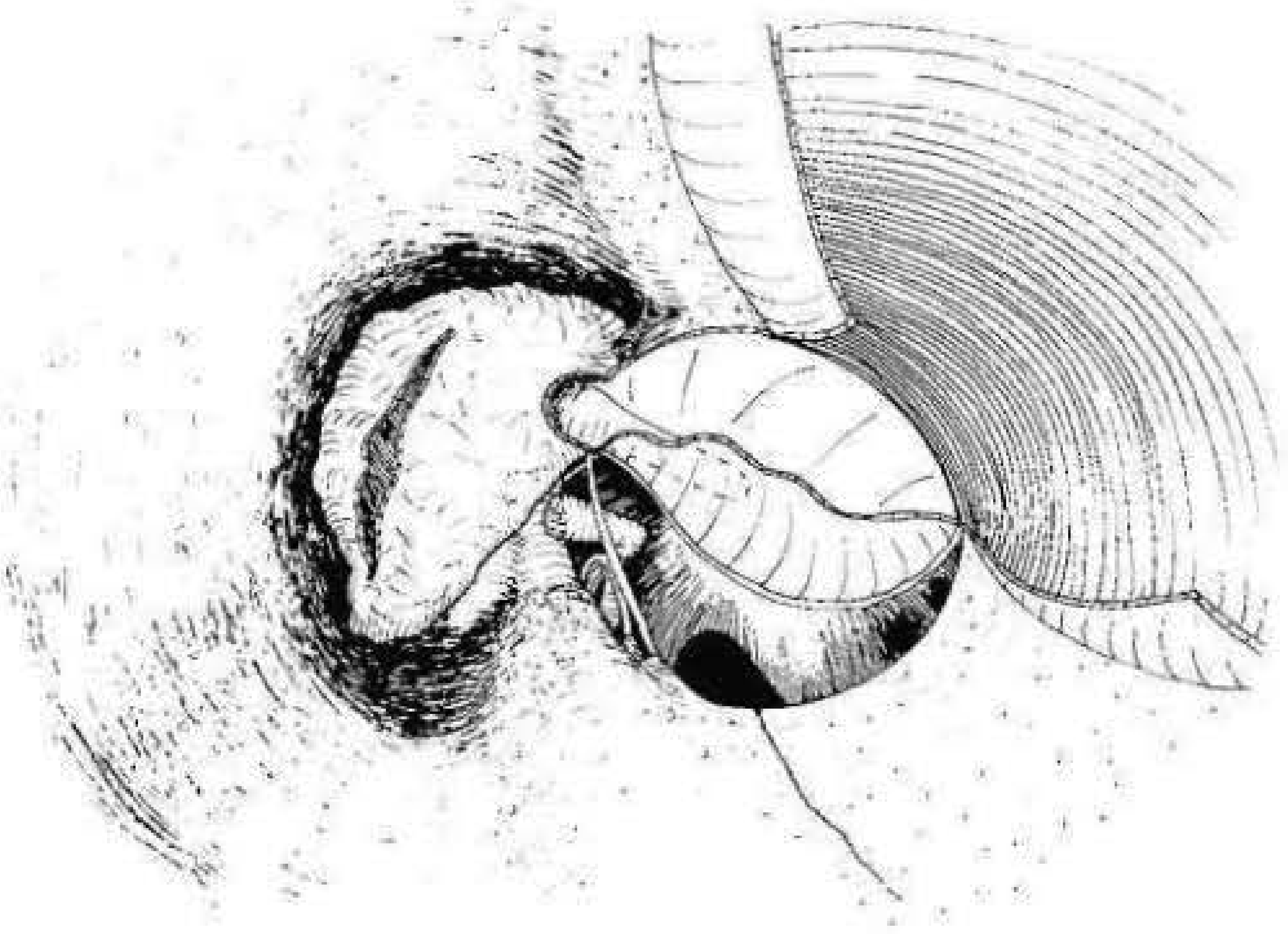


Fig. **636** The attic cholesteatoma has destroyed the incus body and the malleus head. It is elevated from the remnant of the long process of the incus, which is attached to the stapes

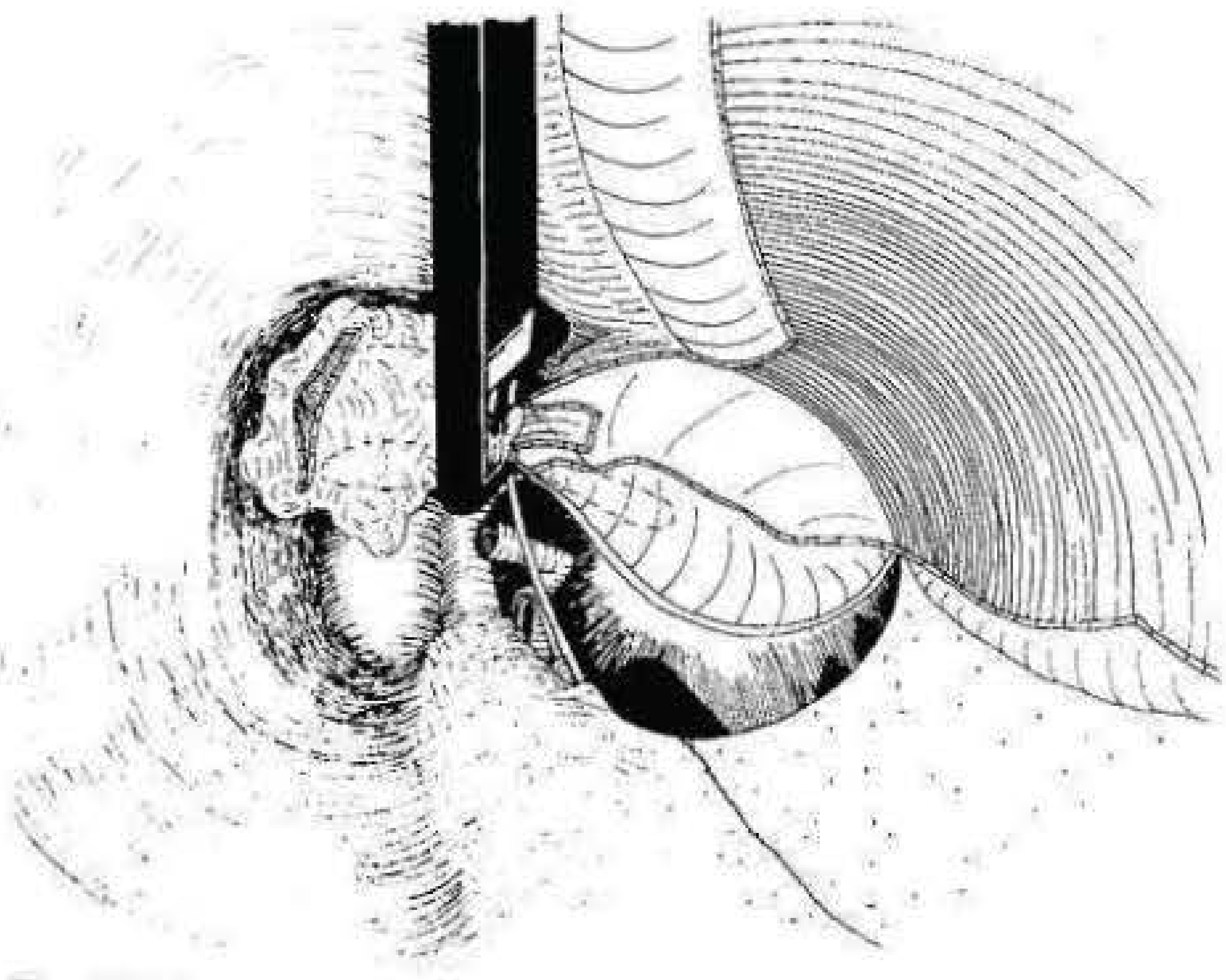


Fig. **637**

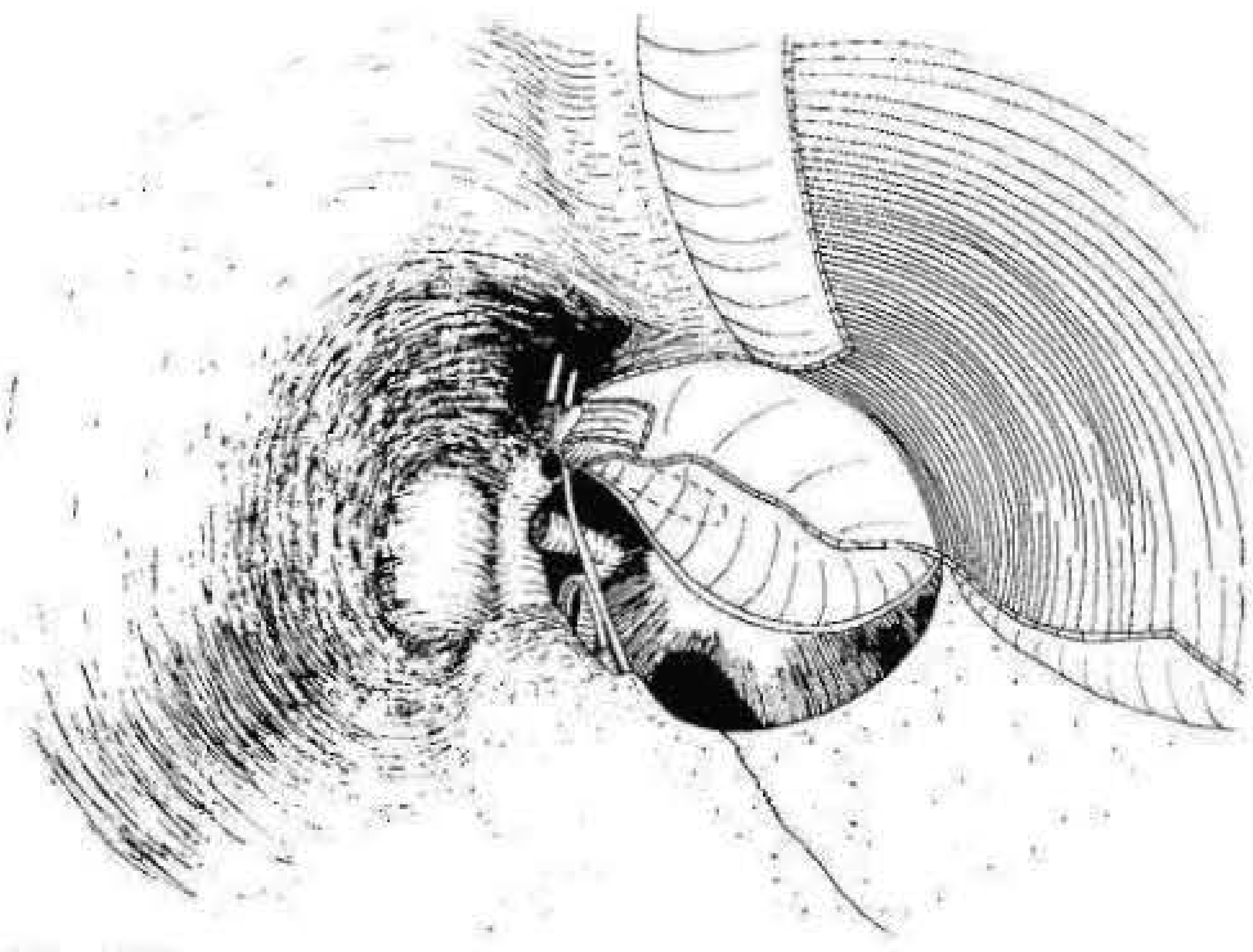


Fig. **638**

Fig. **637** The remnant of the cholesteatoma, with the malleus head, is elevated from the medial wall, and the malleus head is resected by placing a punch just superior to the chorda tympani and the attachment of the tensor tympani muscle to the malleus

Fig. **638** **The final result of canal wall–down mastoidectomy** in the removal of attic cholesteatoma, with a smooth medial attic wall, no bony overhangs on the cavity walls, a smooth transition from the anterior ear canal wall to the cavity wall, and a low facial ridge

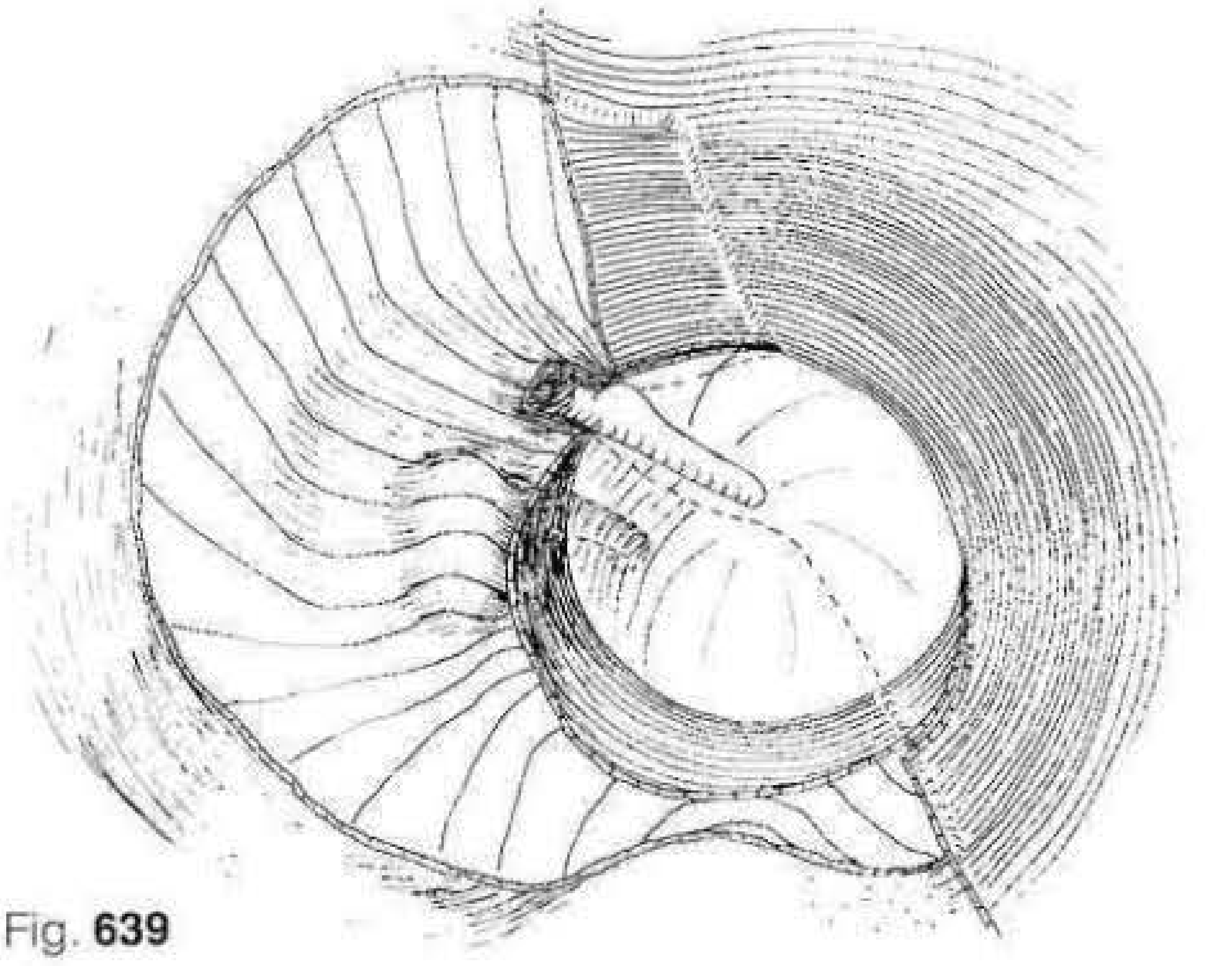


Fig. **639**

Fig. **639** **Reconstruction of the tympanic cavity and attic.** A piece of fascia is placed under the anterior drum remnant and onto the remnant of the malleus, along the malleus handle and under the posterior part of the drum. The fascia covers the entire medial wall of the attic and aditus ad antrum, and extends onto the tegmen antri and facial ridge. The canal skin flaps are replaced. The result is an open aditus, but the inferior part of the cavity can be obliterated, if desired

Transmeatal Inside-Out Canal Wall–Down Mastoidectomy

Transmeatal canal wall–down mastoidectomy with either a retroauricular or an endaural approach can start medially, and this is commonly used in two situations:

1. Attic cholesteatoma with massive erosion of the lateral attic wall (Fig. **640**), where it is evident that the ear canal wall has to be removed, and a kind of Bondy's operation or marsupialization of the cholesteatoma is performed.
2. In many cases, the surgeon prefers to follow the cholesteatoma in a posterior direction, starting with an atticotomy and continuing with an aditotomy and antrotomy, always with the chance of avoiding excess bone removal and thus avoiding a larger mastoidectomy if there is no further extension of cholesteatoma into the antrum or mastoid air cells. Cases with sinus cholesteatoma extending into the posterior attic and aditus ad antrum are another common situation suitable for inside-out mastoidectomy.

Inside-out mastoidectomy is also termed "retrograde mastoidectomy", and is performed either with a retroauricular or an endaural approach.

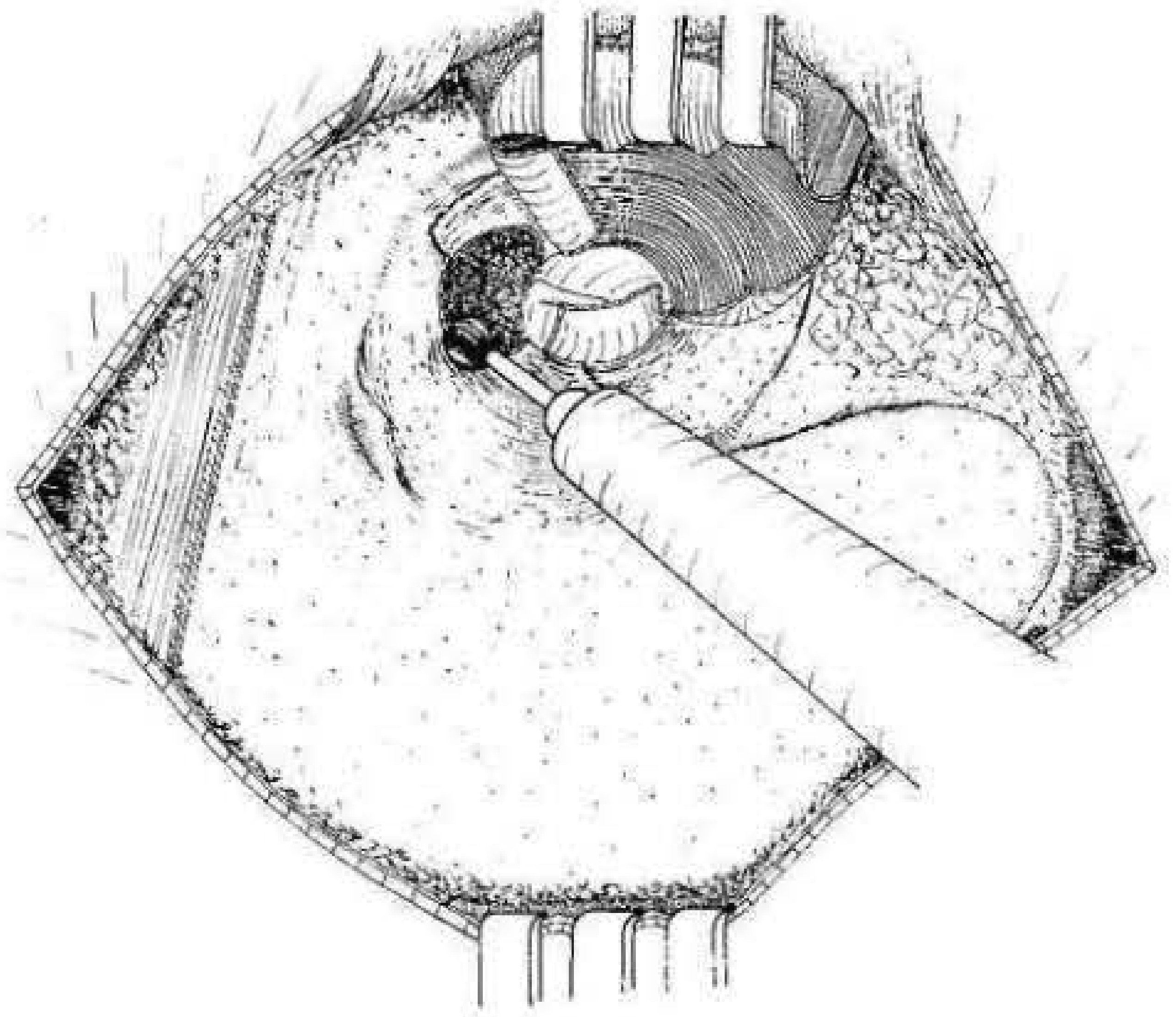


Fig. **640** **Retrograde mastoidectomy in an attic cholesteatoma with huge erosion of the lateral attic wall.** The retroauricular approach is used, the subcutis–muscle–periosteum anterior-pedicled flap is elevated, the ear canal skin flaps are elevated, and the tympanic cavity is entered. The large attic erosion is visible, and mastoidectomy starts at the lateral edge of the erosion using a large cutting burr

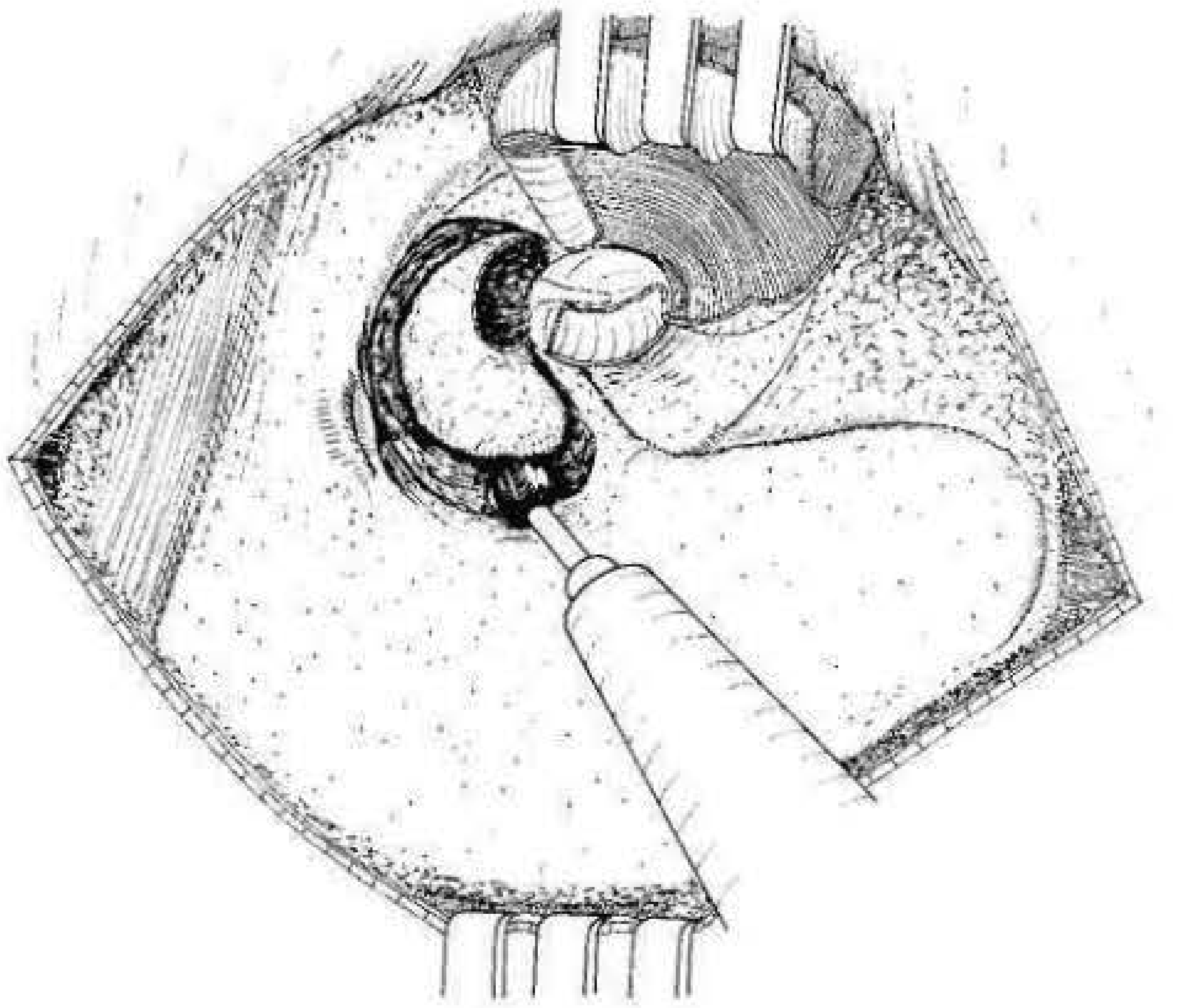


Fig. **641** After removal of the lateral attic wall, the cholesteatoma membrane is exposed, and further drilling and enlargement of the ear canal is taking place

Retrograde Mastoidectomy with Massive Erosion of the Lateral Attic Wall

In these cases, the pars tensa is usually intact and the medial membrane of the cholesteatoma sac is visible through the large attic defect, so that the site of initial drilling is clearly indicated by the pathology. Although an attic cholesteatoma with extensive erosion can be treated in many ways, many surgeons perform a canal wall–down mastoidectomy, starting the drilling at the lateral border of the huge attic defect (Fig. **640**) and continuing in a posterior direction as long as the cholesteatoma sac is visible. This is the quickest and most efficient method, and can, of course, also be performed using an endaural approach.

After an anteriorly-based subcutis–muscle–periosteum flap has been elevated in a retroauricular flap approach (Vol. 1, Figs. **135–147**), and after the posterior ear canal skin has been elevated by performing a medial circumferential incision between the 12-o'clok, and 6-o'clock positions and two radial incisions at the 12-o'clock and 6-o'clock positions, the entire ear canal wall and mastoid plane are exposed. Drilling continues at the lateral edge of the spontaneous erosion of the bony ear canal using a large cutting burr (Fig. **640**), and proceeds in a posterior direction, enlarging the ear canal and gradually opening the attic, aditus an antrum, and antrum, exposing more and more of the cholesteatoma sac (Fig. **641**). At this stage, drilling is still concentrated around the ear canal, and the suprameatal spine remains.

With continuous drilling in a posterior direction, the posterior ear canal wall and the cortical bone of the mastoid plane and the lateral mastoid cells are removed, exposing the cholesteatoma sac. With a curved rugine placed between the bone and the cholesteatoma sac, the further posterior extent of the cholesteatoma can be determined. If the cholesteatoma is small, occupying only a small antrum surrounded by sclerotic bone, little additional drilling is needed to exenterate the entire cholesteatoma, and the result is a small Bondy's operation leaving the matrix in place, or an atticoantrotomy with removal of the matrix.

Usually, the cholesteatoma is more extensive, and further drilling is required along the mastoid tegmen up to the middle fossa dura, as well as to the inferior part of the bony ear canal, creating a small cavity and exposing more of the cholesteatoma (Fig. **642**). The extent of the drilling now resembles a small atticoantrotomy, and if the cholesteatoma does not extend further posteriorly, no more drilling is required. Of course, all the walls have to be polished and the facial ridge lowered.

Further extension of the cholesteatoma or extensive pneumatization requires further drilling, and the cavity increasingly resembles that in a canal wall–down mastoidectomy with the retroauricular approach, resulting in exposure of the entire mastoid tegmen, the sinodural angle, and the bony plate covering the sigmoid sinus, providing a view of the borders of the cholesteatoma sac. When this view is established, an incision of the sac is performed, the lateral part of the matrix is removed, and the cholesteatoma mass is removed (Fig. **643**), exposing the medial wall of the cholesteatoma matrix.

The extent of pneumatization, especially of the mastoid tip, decides how far the exenteration of the cells has to proceed. After all walls have been polished and all major air cells have been exenterated, decisions should be taken a) on whether the cholesteatoma matrix can be removed or not; b) on whether the cavity should be obliterated or not; and c) on whether the ear canal should be reconstructed. Very few surgeons will attempt to repneumatize the mastoid cavity in this situation.

If the hearing is reasonable, the pars tensa is intact, and the medial part of the matrix does not involve, any perilabyrinthine cells, the cavity can be left as in a Bondy's operation or as a conservative radical cavity with marsupialization, leaving the epithelial membrane or part of it in place, polishing the cavity walls, and lowering the facial ridge (Fig. **644**).

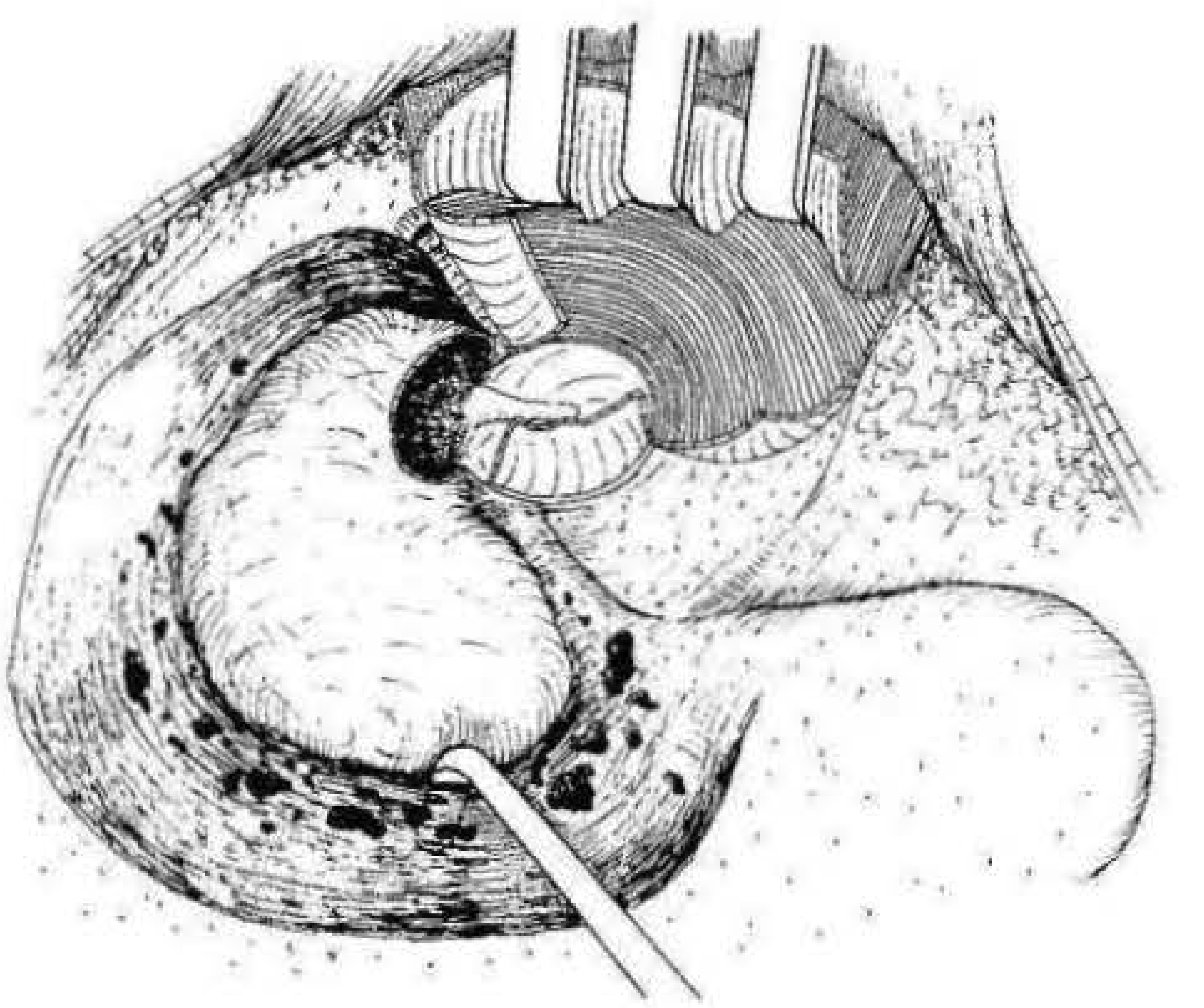


Fig. **642** The extension of the cholesteatoma is followed posteriorly by removal of the bone, enlargement of the ear canal, and removal of the cortical bone. The mastoid cells are exenterated, and the atticoantrotomy is performed. Further extension of cholesteatoma is investigated using a curved rugine

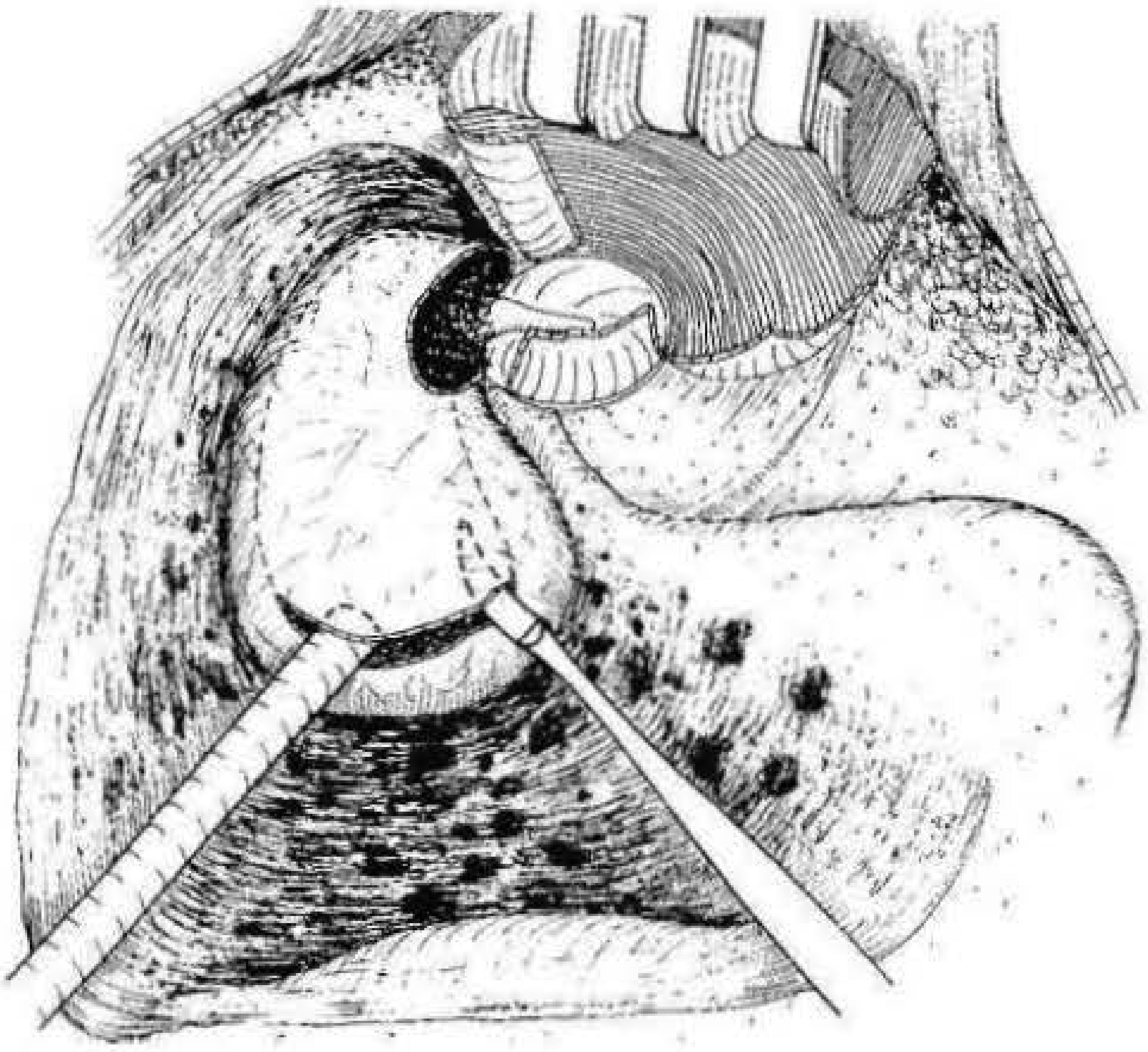


Fig. **643** In further extension of the attic cholesteatoma, a large canal wall–down mastoidectomy is performed. The cavity walls are smoothed, the cholesteatoma sac is demarcated, opened using a sickle knife, and debulked using a large suction tube. The dashed line indicates the removal of the lateral wall of the cholesteatoma sac

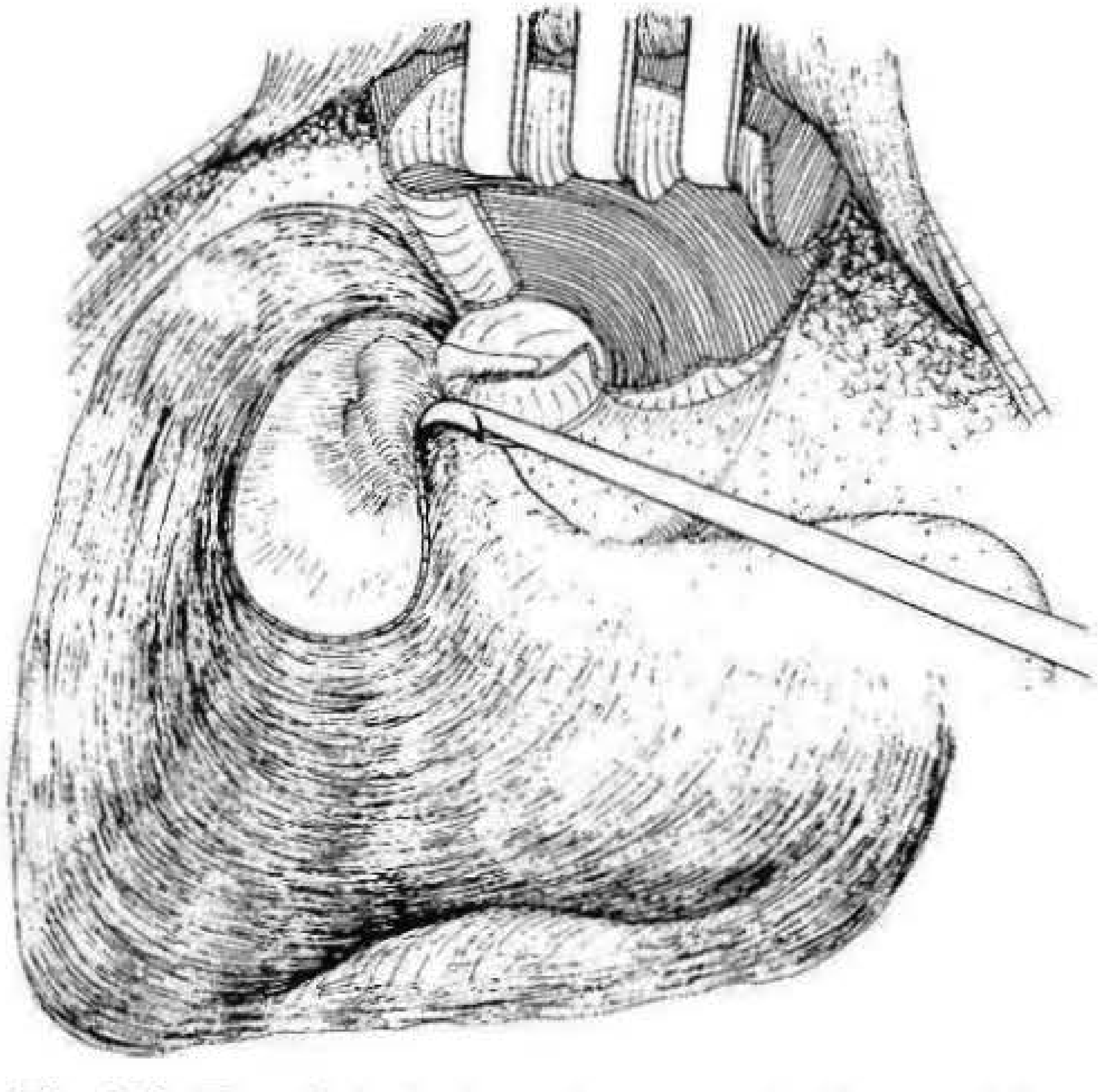


Fig. **644** The cholesteatoma is removed. The medial cholesteatoma membrane is cleaned, ensuring that no cholesteatoma extends into the perilabyrinthine cells. Since the hearing is good and the ossicular chain is intact, a Bondy's operation is performed, leaving the cholesteatoma matrix in place on the medial wall and on the ossicles. All the overhangs are carefully removed using a diamond burr or a House curet. The remnant of the posterior buttress is removed using the House curet

The advantage of retrograde mastoidectomy is that an inside-out mastoidectomy follows the pathology safely along the middle fossa dural plate, with constant precise control of the position of the burr, so that drilling in a posterior direction along the middle fossa dural plate can be performed rapidly. Even when one is using a large, safe diamond burr, relatively rapid drilling can be performed whilst exposing the cholesteatoma. The surgeon has to decide whether the pneumatization requires further exenteration of the air cells, or whether a small cavity can be created. On the other hand, retrograde mastoidectomy with a retroauricular approach permits as large a cavity as is necessary. The extent of drilling can be as large in inside-out transmeatal canal wall–down mastoidectomy as it is with the outside-in method (Figs. **623, 624, 629, 630**) and as large as in transcortical mastoidectomies (Figs. **580–584**).

Retrograde Mastoidectomy on Demand

In contrast to the obvious attic cholesteatoma cases with massive resorption of the attic wall, there are many other cases of small cholesteatomas—especially of the pars tensa—in which the surgeon may start elevating the cholesteatoma from the tympanic cavity before recognizing that it extends posteriorly, through the tympanic isthmus, up to the attic. Such cases are often sinus cholesteatomas involving mainly the tympanic sinuses and extending to the attic. In these cases, limited mastoid surgery may provide a good solution, and a retrograde mastoidectomy is, in the present author's opinion, a valuable option.

In sinus cholesteatoma, when one starts with elevation of the cholesteatoma membrane from the tympanic sinus (Fig. **645**), and then assess the extension of the cholesteatoma toward the attic a large otosclerosis drilling can be performed (Fig. **646**). If the cholesteatoma cannot be removed by removing the posterosuperior annulus, drilling is continued toward the aditus, gradually removing the lateral attic wall and exposing the incus body and the cholesteatoma (Fig. **647**). If the cholesteatoma, together with the incus, can safely be removed, the small aditotomy can be closed with a piece of bone or cartilage, and an ossiculoplasty can be performed (Figs. **648, 649**).

If the cholesteatoma extends further, an extended aditotomy and atticotomy is performed by removing more of the lateral attic wall, exposing the malleus head, and drilling toward the tegmen tympani (Fig. **650**). If the cholesteatoma can safely be removed together with the incus body, the attic defect can be covered by bone or cartilage, and ossiculoplasty and tympanoplasty can be performed (Fig. **651**).

In case of further extension of cholesteatoma into the antrum, the drilling is continued toward the

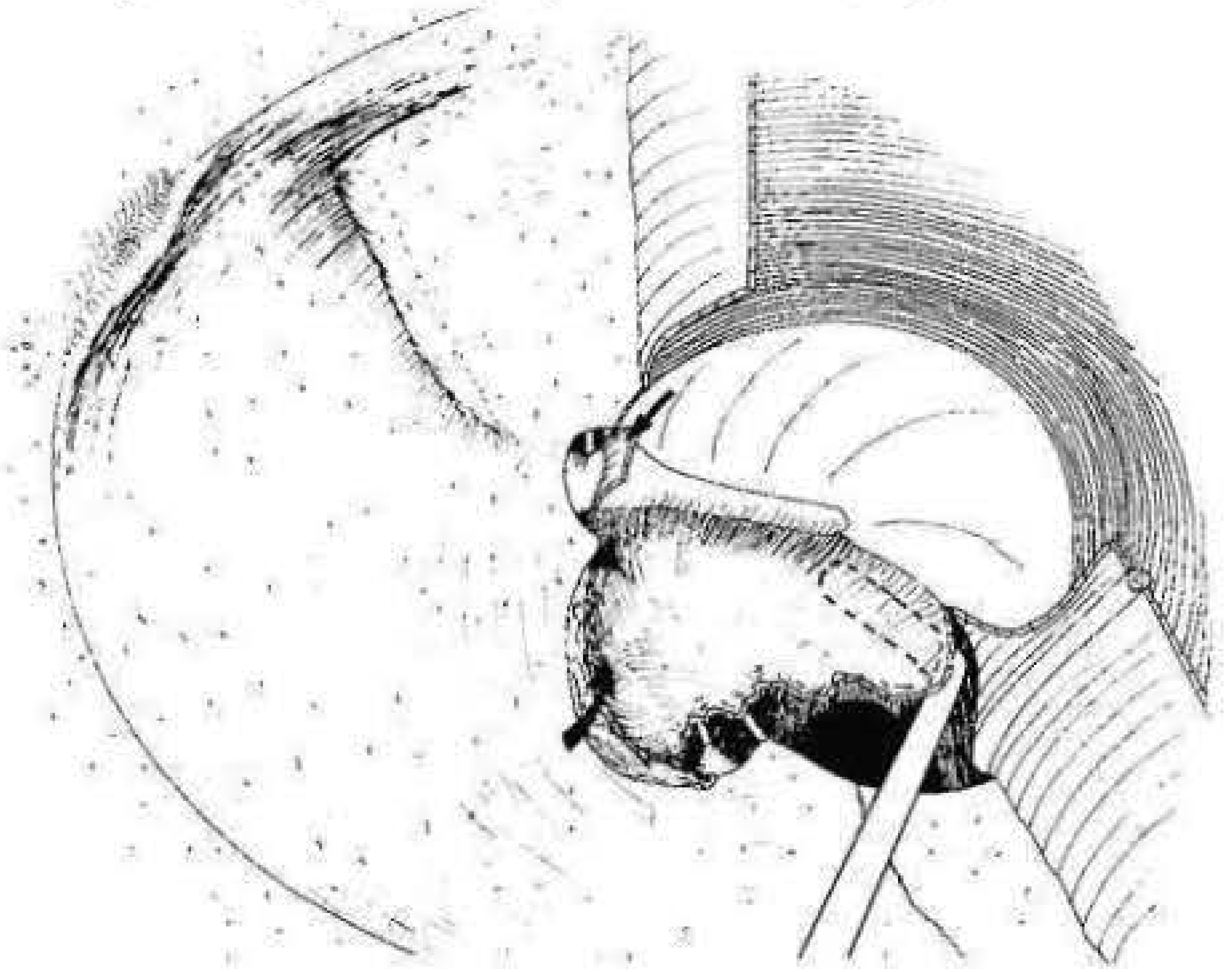


Fig. **645** **Inside-out transmeatal canal wall–down mastoidectomy in a retroauricular approach for sinus cholesteatoma.** A sinus cholesteatoma membrane is elevated from the inferior part of the tympanic cavity, tympanic sinus, and round window niche region. Otosclerosis drilling is performed to inspect the extension of the sinus cholesteatoma toward the attic (curved arrow). The long process of the incus has been resorbed, as have the stapes crura. Shrapneil's membrane is elevated (straight arrow)

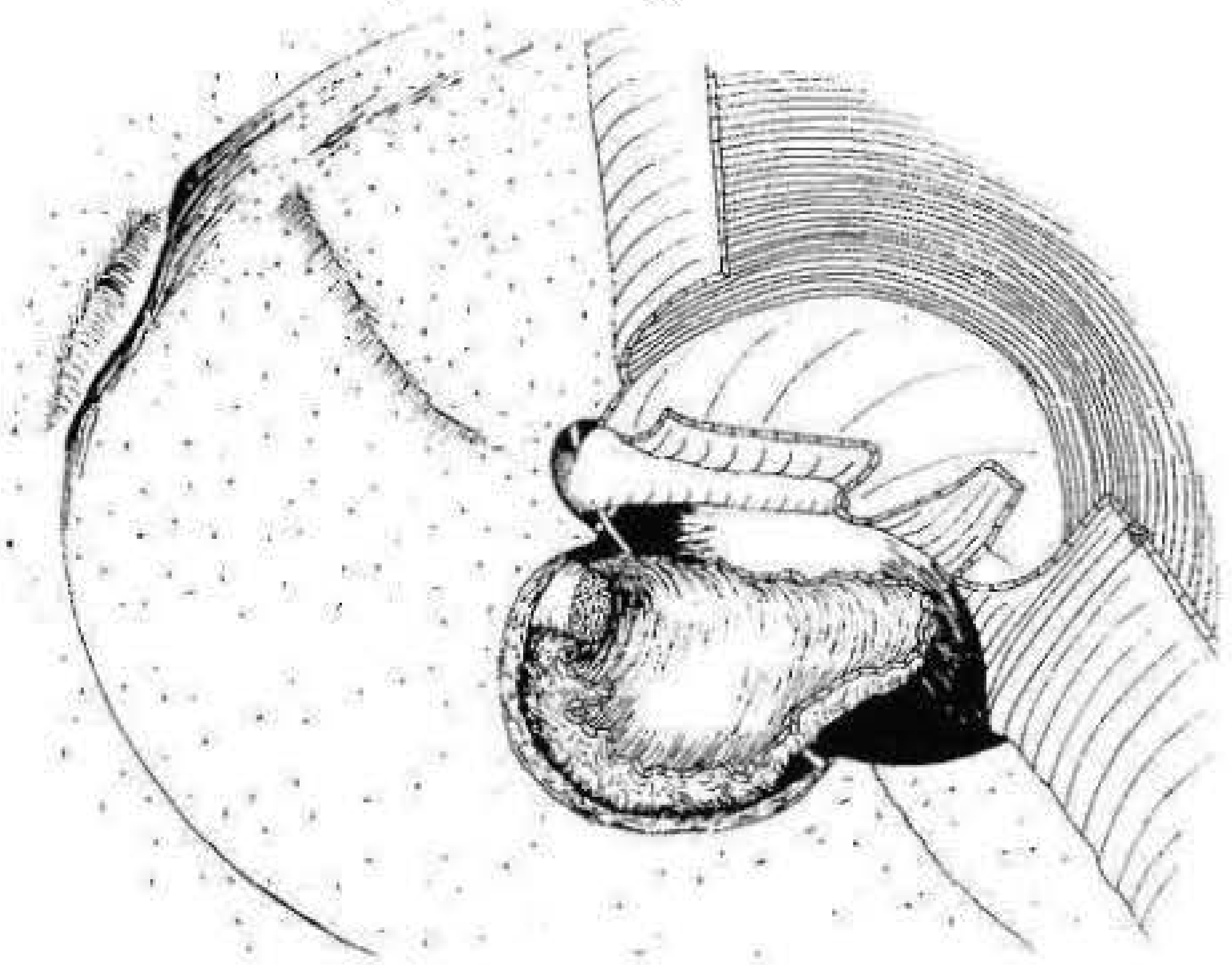


Fig. **646** Further otosclerosis drilling of the long bony annulus indicates the extension of the cholesteatoma into the attic

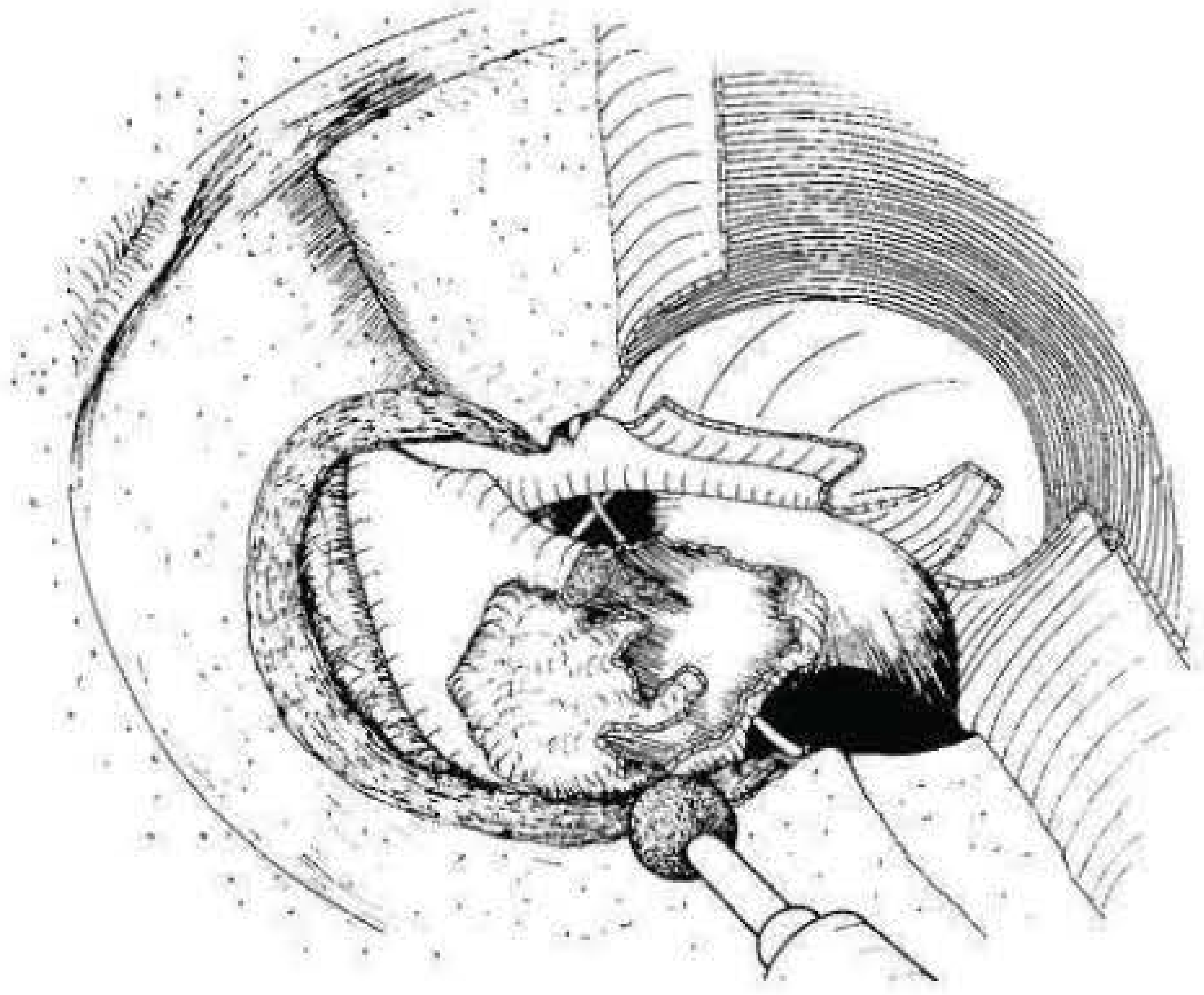


Fig. **647** **Aditotomy.** An aditotomy is performed using a diamond burr, exposing the incus body and the cholesteatoma. In the tympanic cavity, the cholesteatoma membrane is separated from the remaining malleus handle and elevated, and the drum is prepared for later myringoplasty

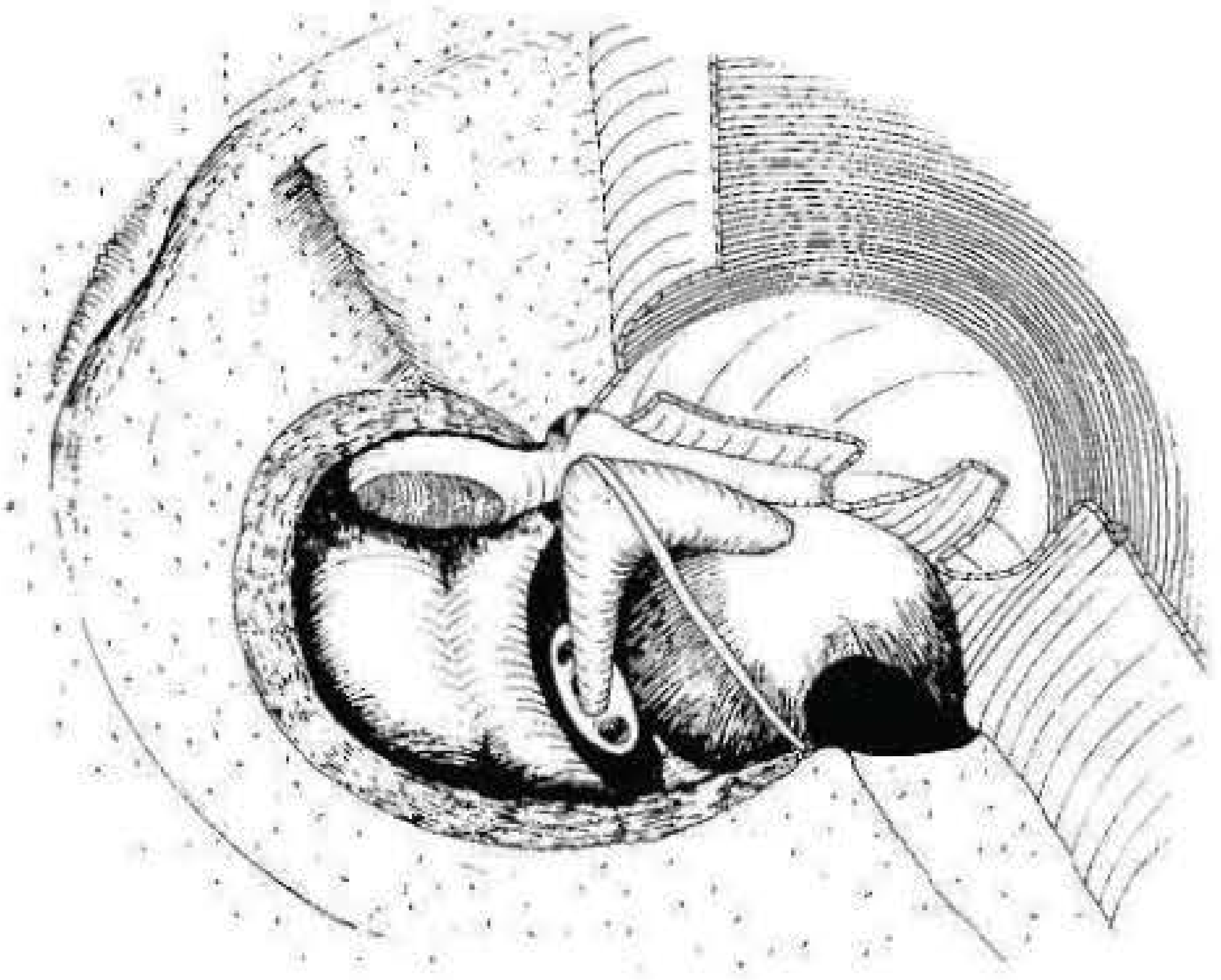


Fig. **648** The cholesteatoma is safely removed and the attic cleaned. An incus columella is placed with its short process on the footplate, with the incus body parallel to the malleus handle

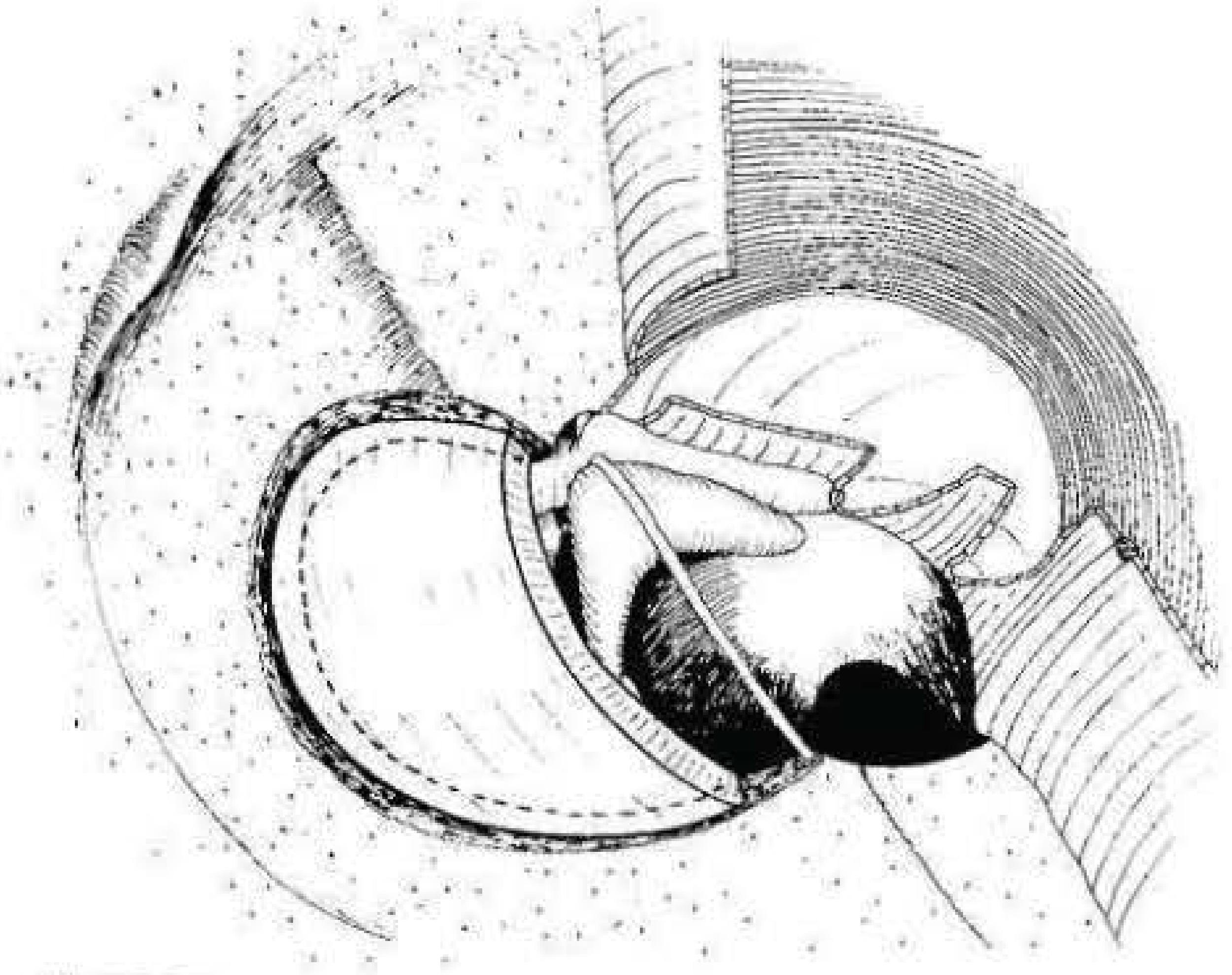


Fig. **649**

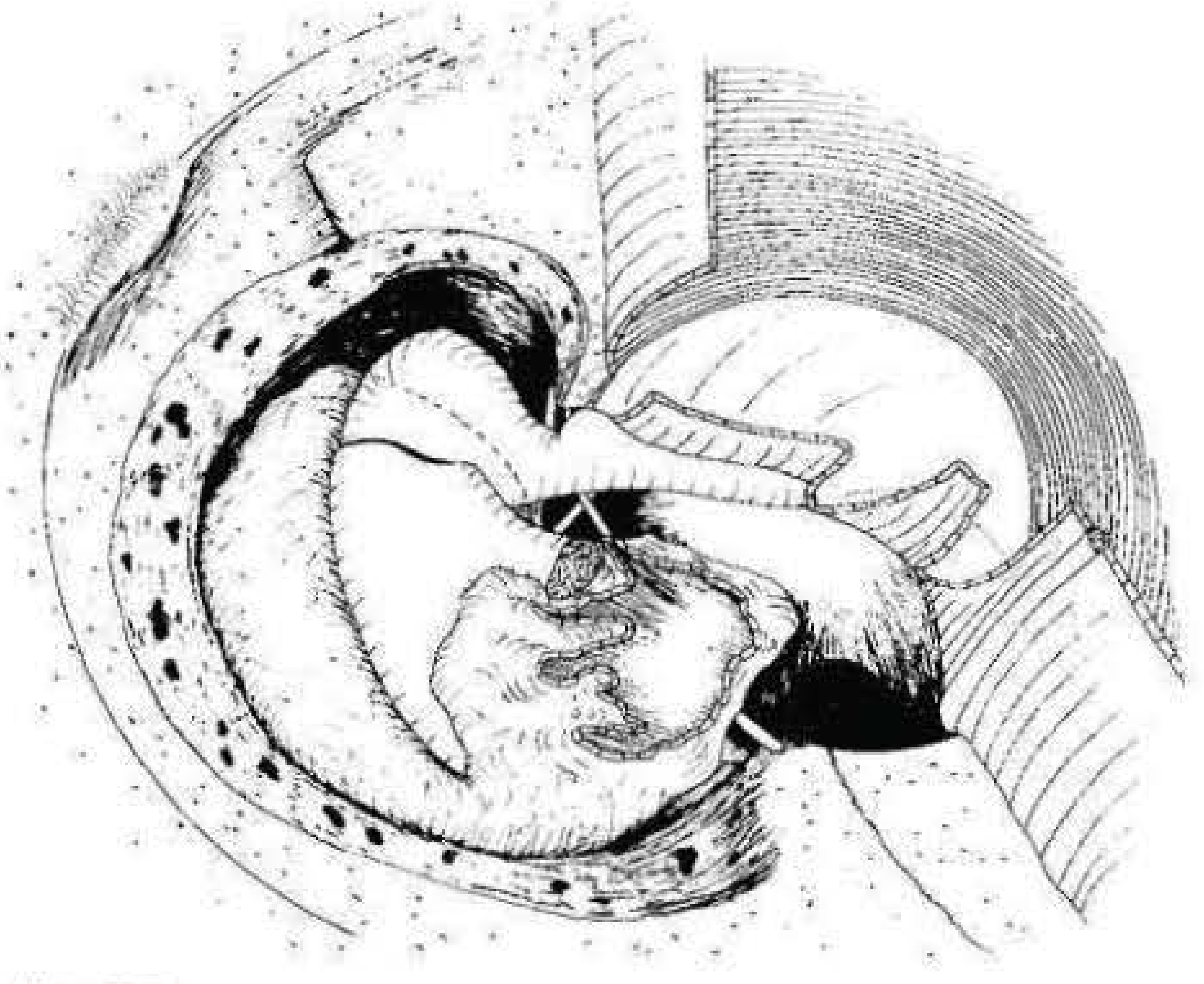
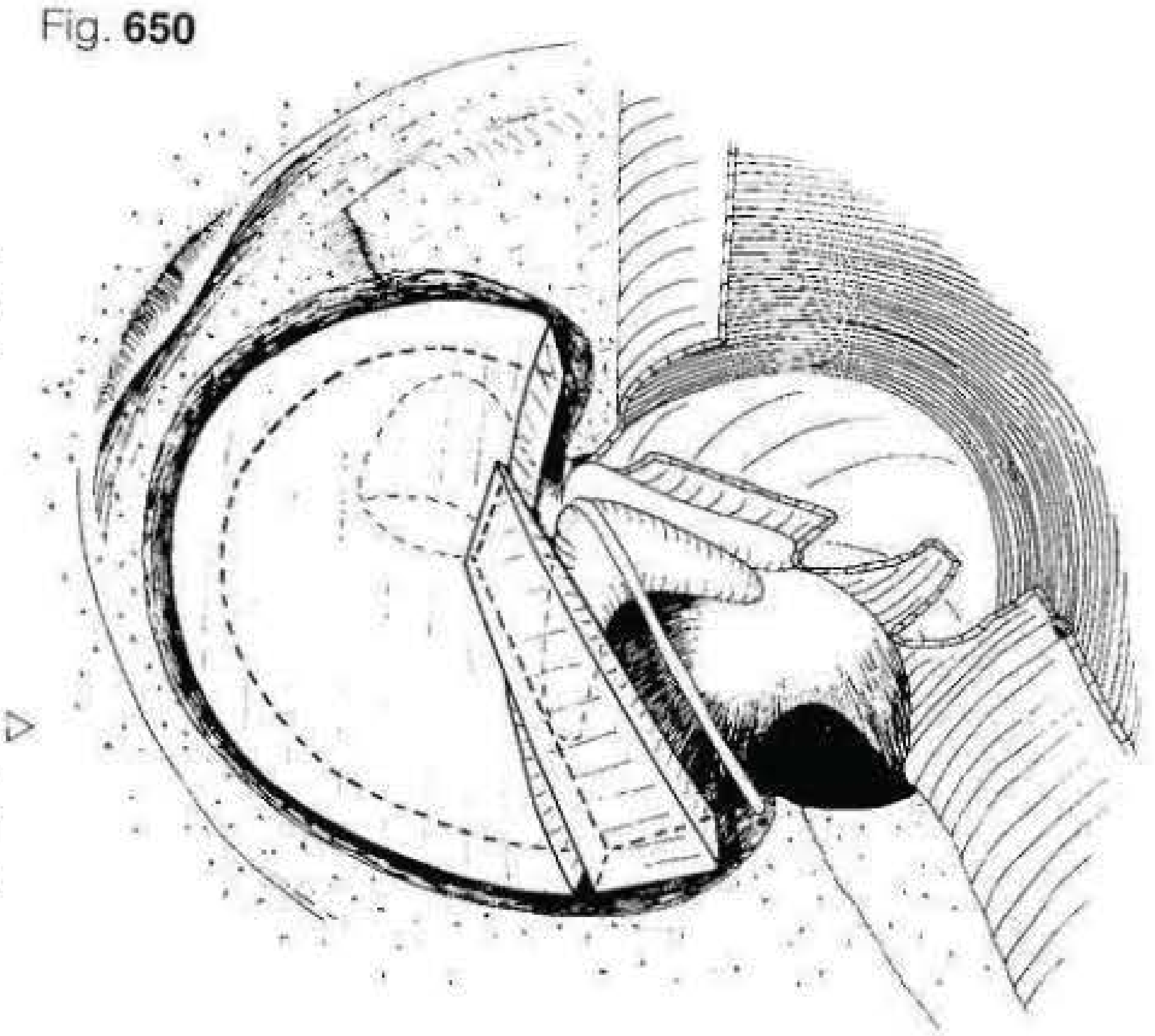


Fig. **650**

Fig. **649** **Reconstruction.** The aditotomy is closed with a cartilage plate

Fig. **650** **Atticoantrotomy.** An atticoantrotomy is performed, following the cholesteatoma into the antrum. It extends under the malleus head, but not into the anterior attic

Fig. **651** **Reconstruction.** After removal of the ▷ cholesteatoma and extrusion of the incus, the large bony defect is covered with a cartilage plate. The incus is used as a columella, and a small cartilage plate closes the defect after the otosclerosis drilling



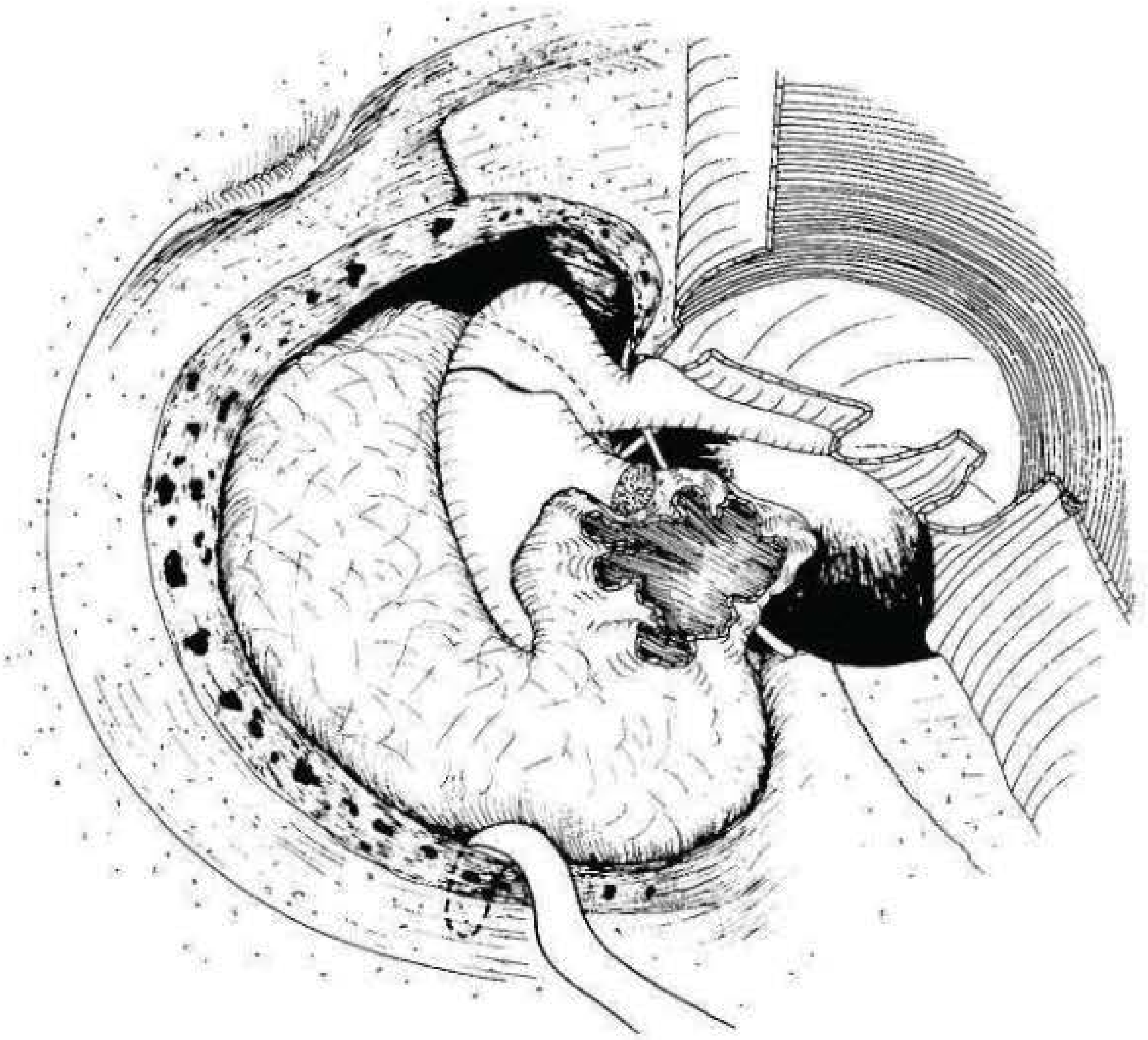


Fig. **652** An atticoantrotomy is performed by extensive removal of the bone towards the tegmen antri and tegmen tympani. Much of the cholesteatoma is exposed, but the inferior and superior borders have still not been determined, and further drilling is needed

tegmen tympani and tegmen antri, as well as in an inferior direction, with a small atticoantrotomy being performed (Fig. **652**). Safe removal of cholesteatoma permits reconstruction of the ear canal with bone or cartilage plates using the same principles as shown in Figure **651.**

If the cholesteatoma extends beyond the antrum, the atticoantrotomy has to be extended into a small canal wall–down mastoidectomy, but even in these cases the ear canal wall can be reconstructed with cartilage and the cavity repneumatized (Fig. **653**).

In cases with further extension of cholesteatoma, a large retrograde canal wall–down mastoidectomy is performed by removing all the bone along the middle fossa dura, polishing the walls, removing all bony overhangs (Fig. **654**), exenterating the cells from the sinodural angle and posterior fossa dura, and lowering the facial ridge.

The retrograde mastoidectomy is now complete, and cholesteatoma removal can start. The cholesteatoma is demarcated and elevated as a sac (Fig. **654**). The sac is then opened, and the cholesteatoma is debulked using a large suction tube. The cholesteatoma membrane is then gradually and carefully elevated from the medial wall of the antrum and pushed toward the lateral semicircular canal using a cottonoid ball (Fig. **655**). The cholesteatoma mass is removed from the malleus region after removal of the incus body and cleaning of the entire tympanic sinus.

After removal of the cholesteatoma, the walls are further polished, all the bony overhangs are removed, and the cavity can either be obliterated or covered with fascia as an open cavity after a columella has been placed on the footplate (Fig. **656**). Retrograde mastiodectomy therefore offers several possibilities, starting with aditotomy, atticotomy, atticoantrotomy, and proceeding to a small or a large canal wall–down mastoidectomy, depending on the pathology and extent of pneumatization.

The principles of reconstruction are the same as in transcortical outside-in mastoidectomy techniques (Figs. **585, 589, 591, 595, 597, 602, 610**). Retrograde mastoidectomy on demand can also be performed with preservation of the bridge. These techniques are described in Chapter 13.

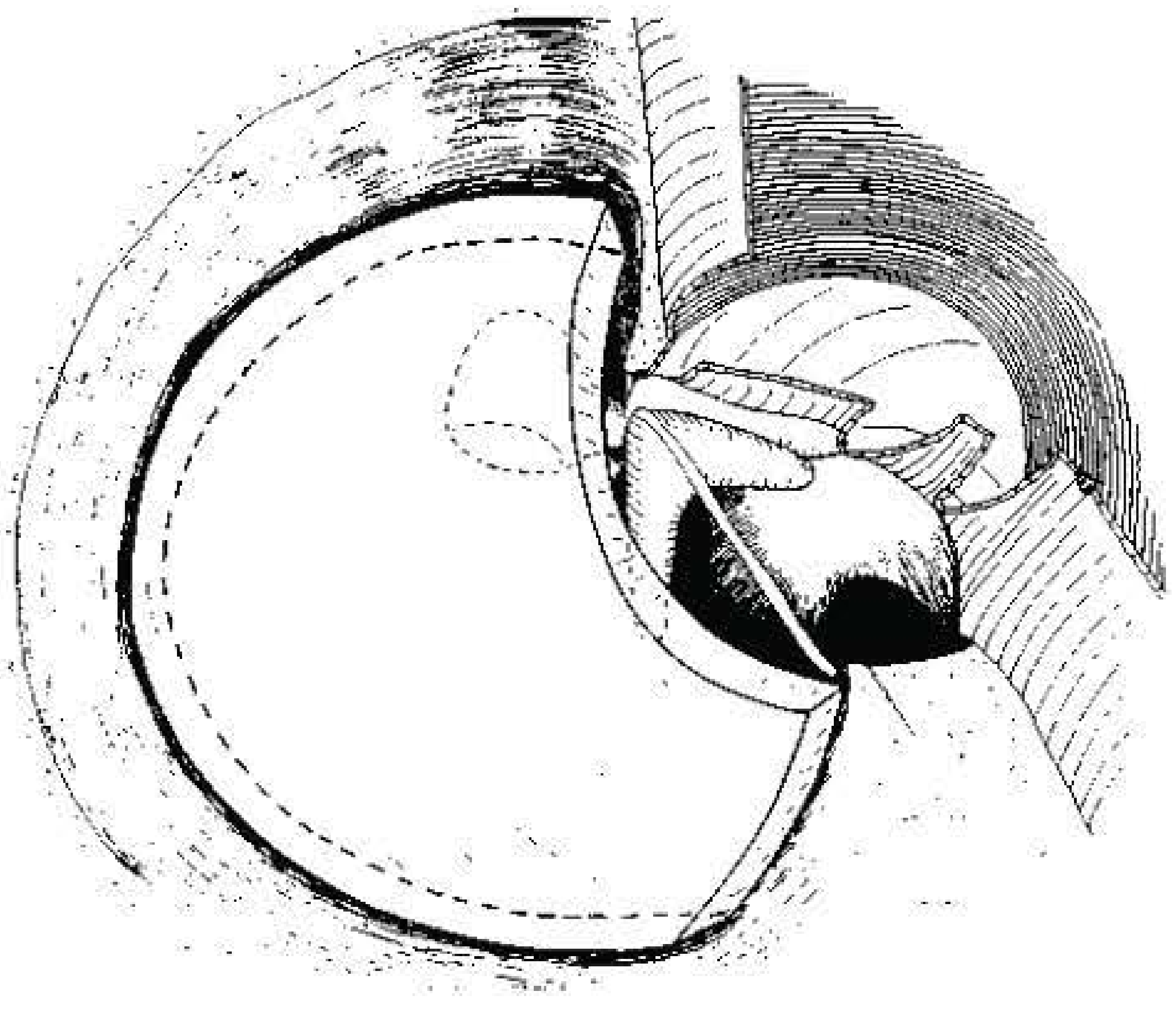


Fig. **653** **Reconstruction.** After further enlargement of the atticoantrotomy drilling, the cholesteatoma is removed, and the large bony defect is covered with a cartilage plate, reconstructing the ear canal wall. The antrum will be repneumatized

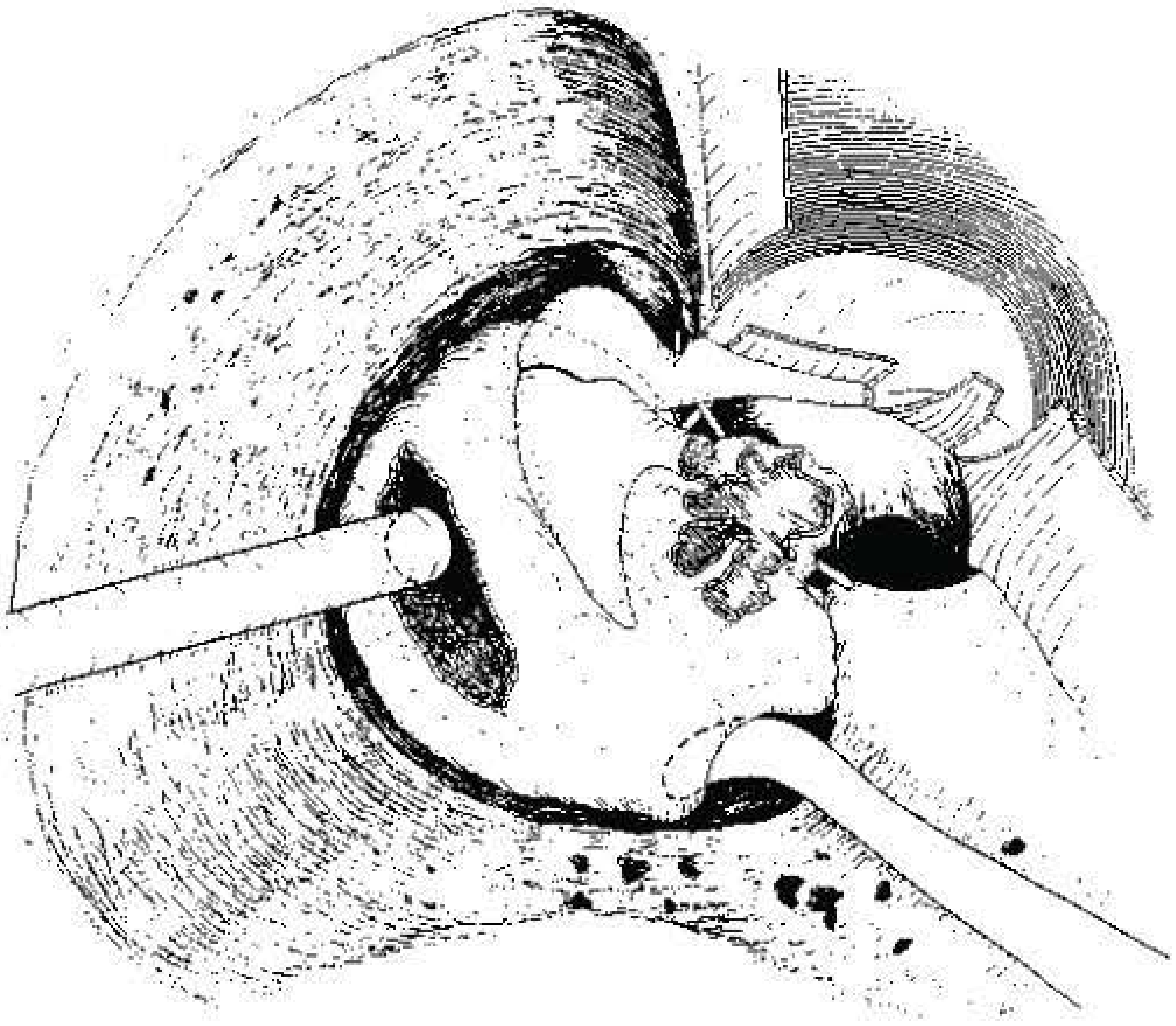


Fig. **654** **Canal wall–down mastoidectomy is performed,** exposing all the cholesteatoma, occupying the entire antrum. The walls are smoothed, and the mastoid cells exenterated. The posterior fossa dural plate is smoothed, and the cells from the mastoid process are removed. The facial ridge is lowered. Elevation of the cholesteatoma sac is started with a large, curved rugine. Debulking of the cholesteatoma is performed using a large suction tube, placed in the most prominent part of the cholesteatoma sac

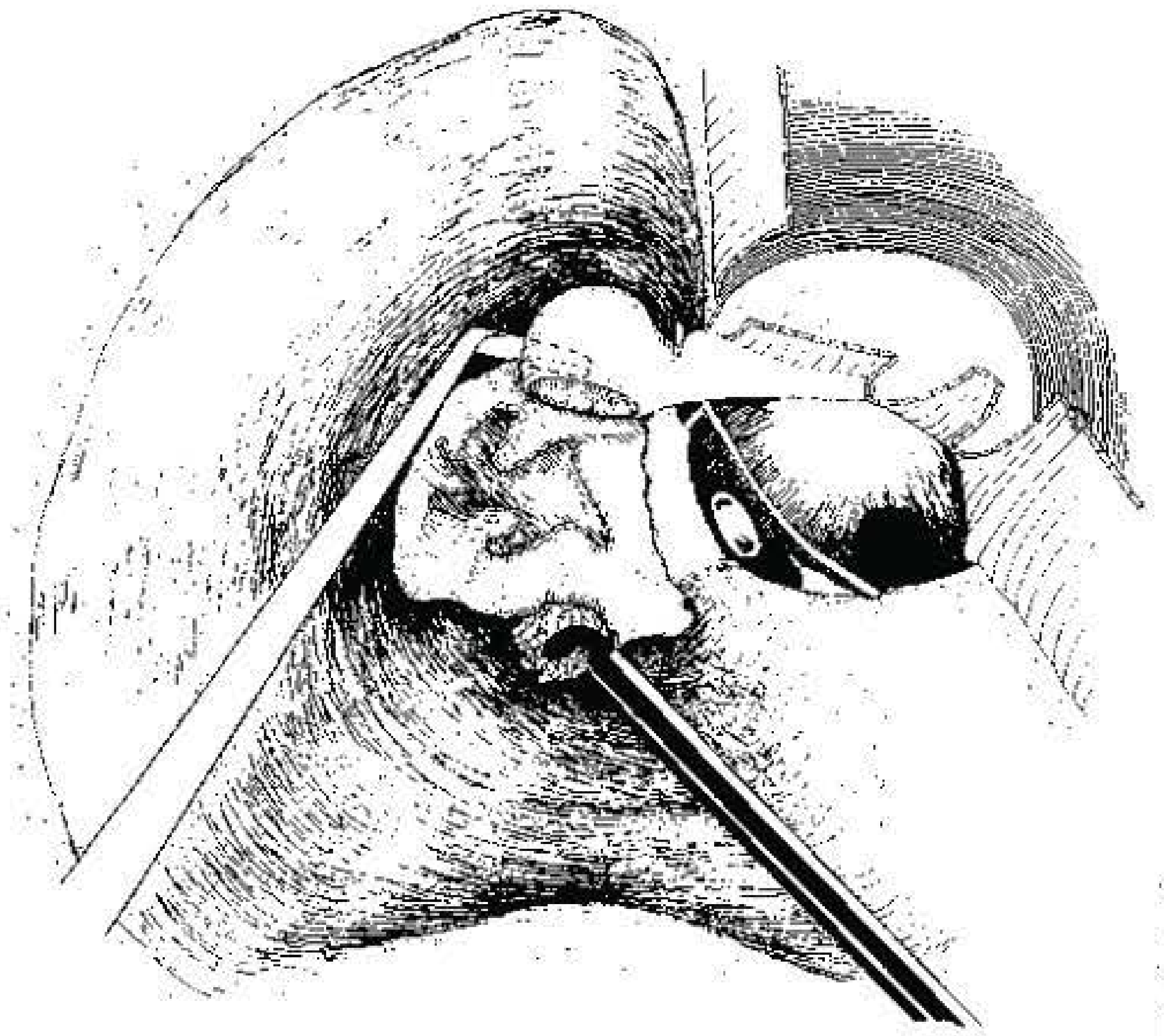


Fig. **655** **Final removal of the cholesteatoma.** The cholesteatoma membrane is pushed toward the lateral semicircular canal using a small cottonoid ball. The cholesteatoma is elevated from the attic region, under the malleus handle, and from the sinus tympani. The footplate and the facial prominence are cleaned. The remaining cholesteatoma is easy to remove from the prominence of the lateral semicircular canal. Finally, all the cavity walls are smoothed, the bony overhangs are removed, and the facial ridge is lowered and smoothed so that reconstruction can start

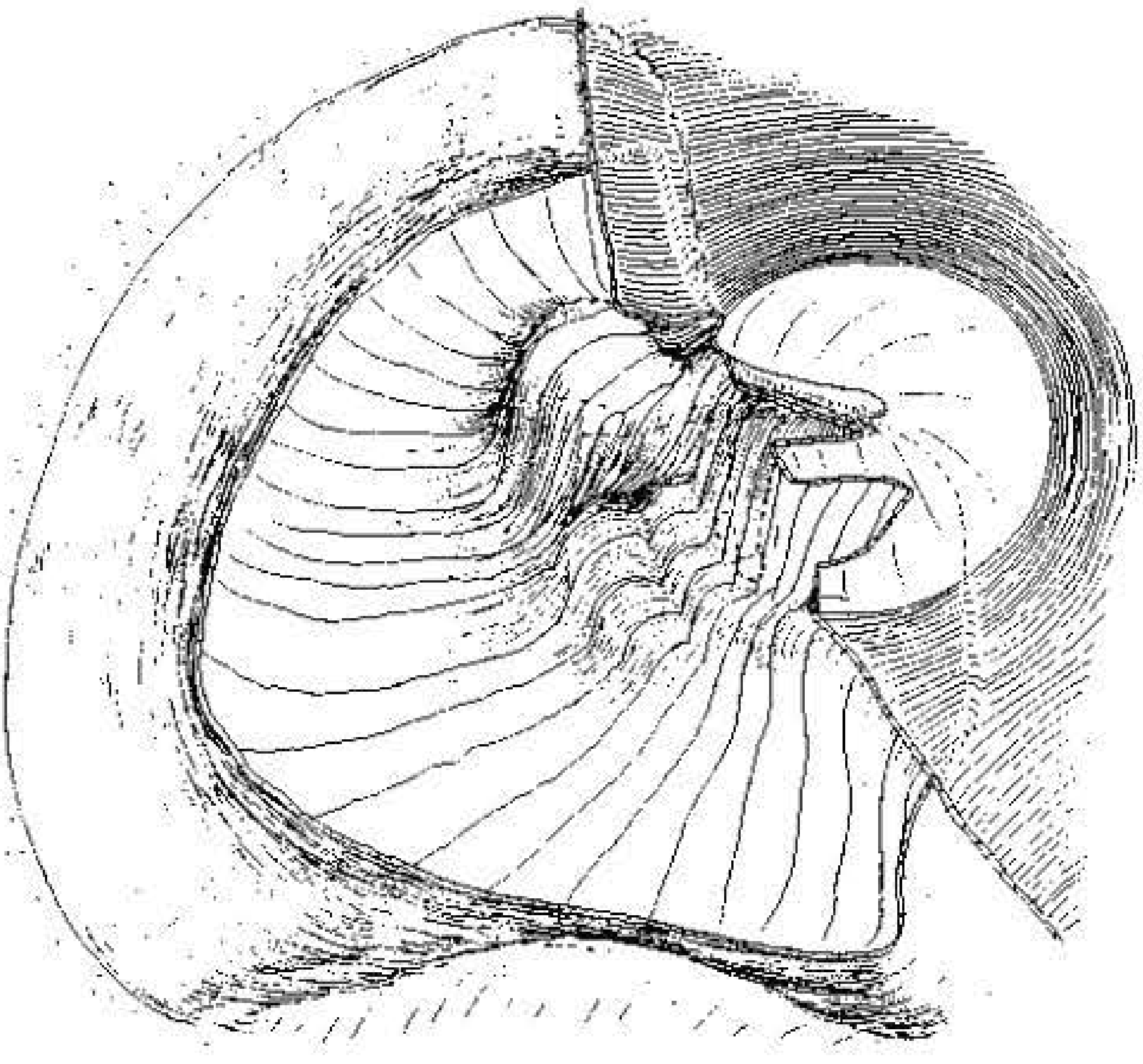


Fig. **656** **Reconstruction of the tympanic cavity and the attic** with a large piece of fascia placed as underlay graft, covering the incus columella, malleus head, and medial walls of the attic, aditus, and antrum

13 Endaural Canal Wall–Down Mastoid Surgery

Endaural mastoid surgery is defined as mastoid surgery performed using the endaural approach and the transmeatal route (Table **6**). Even canal wall–up mastoidectomy can be performed using an endaural approach, although usually all endaural mastoid surgery employs canal wall–down techniques, with the exception of the special techniques of Wigand and Farrior, with some preservation of a displaced bony ear canal wall (Chapters 9 and 10).

History of Endaural Surgery

The history of endaural surgery, in general, starts with the first publication on paracentesis by Cooper (ca. 1800) (cit. Heermann, 1969) and the invention of the ear mirror by Hoffmann (1841). After reports of hearing improvement after paracentesis in chronic tubal stenosis, kessel removed the entire ear drum endaurally (Kessel 1878), and performed sound protection of the round window using remnants of the ear drum in the following year (Kessel 1980). This operation was later described as tympanoplasty type IV by Wullstein (1952).

Kessel's development of endaural radical mastoidectomy for chronic otitis media (1888) started at the same time as the evolution of the retroauricular transcortical radical operation by von Tröltsch (1873), von Bergmann (1889), Zaufal (1890) and Stacke (1893). Kessel endaurally chiseled away the attic wall and the bone between the antrum and the external auditory canal, cleaning the walls thoroughly using curets and extracting the malleus and incus. This endaural radical mastoidectomy was later described by his chief resident, Hoffman (1892).

If the pathology extended beyond the antrum into the mastoid process, Kessel and Hoffmann completed the surgery using a retroauricular mastoidectomy.

Kessel (1888) removed a triangle of the meatal skin to gain space for the endarural approach (Fig. **657**), but because of the restricted field and insufficient visualization without magnification, the endaural mastoidectomy was only performed by a small number of surgeons, and was later described as an entirely new procedure by Thies (1908).

Carlowitz (1919), J. Heermann, Senior (1921) and Richter (1922) adapted the endaural mastoidectomy and reported good results with their improvements. Heermann also introduced an angled handle for the chisels, Gyergyay (1923) recommended a rotating burr, and Stoltenberg–Lerche

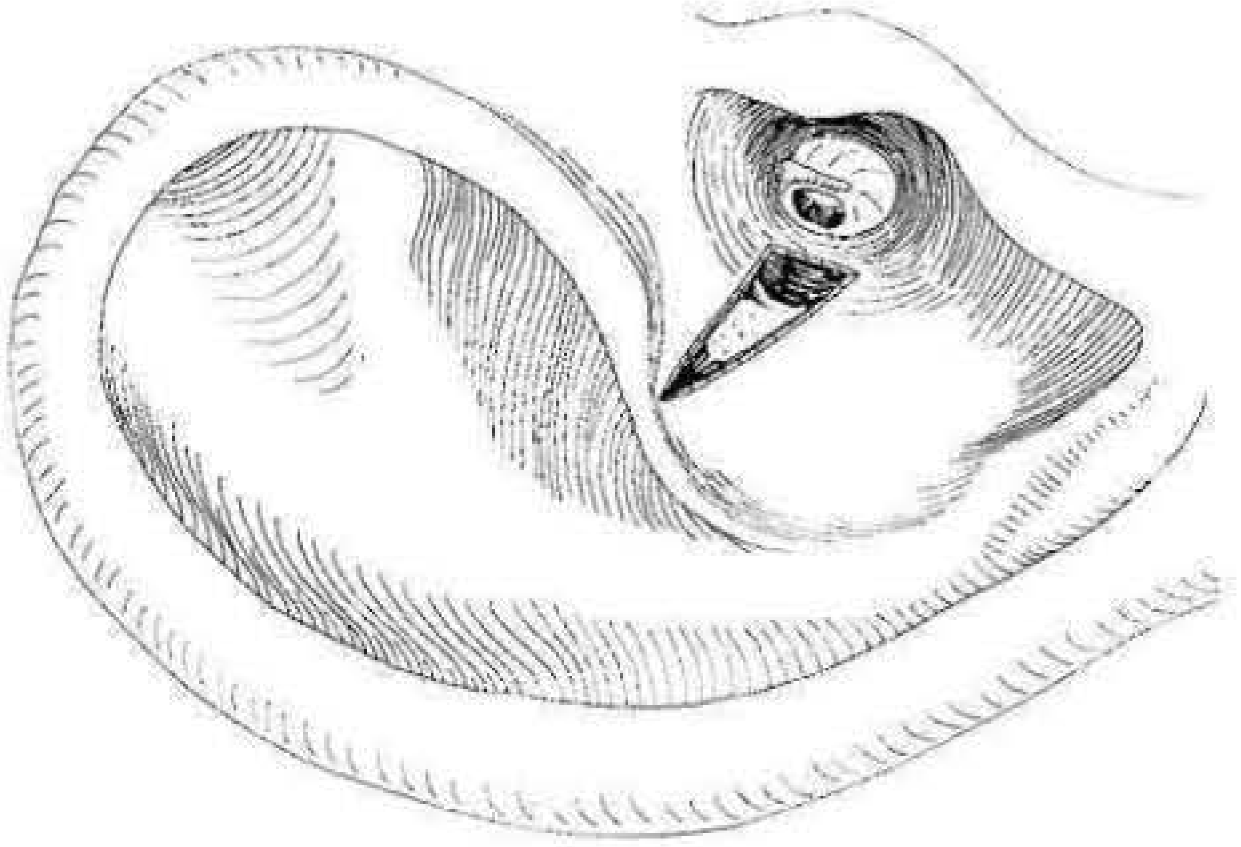


Fig. **657** **The original Kessel endaural incision.** The triangle of excision of the skin and conchai cartilage in the first endaural incision performed by Kessel (after H. Heermann 1969)

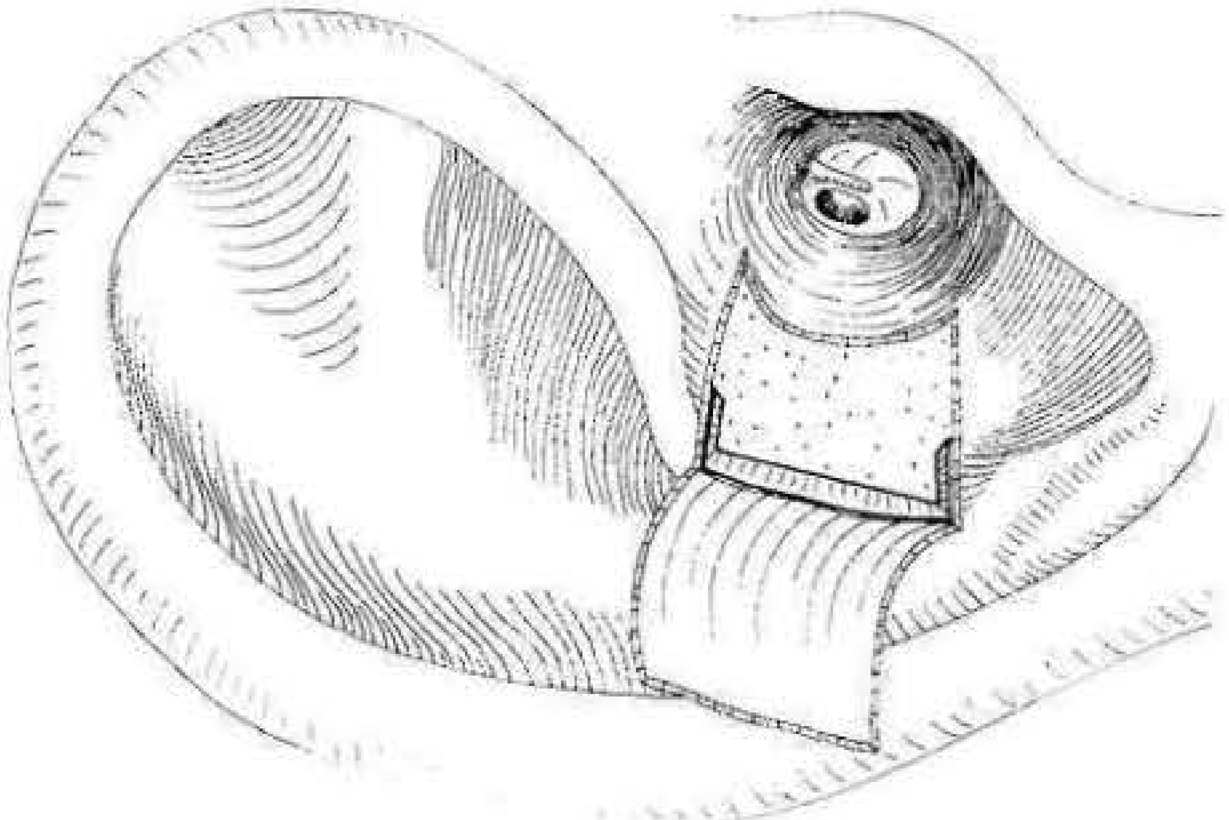


Fig. **658** **The Carlowitz endaural incision** with superior and inferior parallel incisions into the concha of the auricle, removal of the conchai cartilage, and creation of a laterally-based skin flap, similar to K–mer's flap in the retroauricular incision (after H. Heermann 1969)

(1923) introduced the angled handpiece for the burr, to be used for endaural operations.

The narrow operating field was a great inconvenience, and Carlowitz (1919) enlarged the meatus by two parallel incisions placed posteriorly in the concha of the auricle (Fig. **658**), similar to Körner's plastic technique (Körner 1894, 1899) used in retroauricular mastoidectomy. The disadvantage of the incision in the auricular cartilage was the potential for perichondritis, and H. Heermann (1939) therefore described an intercartilaginous endaural incision (Vol. 1, Figs. **27–42,** Chapters 2 and 3). In fact, Botey (1898) had already described an extracartilaginous endaural incision to enlarge the meatus, but he apparently never used it for an endaural operation.

Lempert was a great advocate of endaural mastoidectomy (Lempert 1929). Initially, he used a triangular skin excision, as suggested by Kessel (Fig. **657**). The endaural operation became very popular after the introduction of the one-stage fenestration of the horizontal semicircular canal for otosclerosis. By combining the Heermann extracartilaginous endaural incision with the Surdille tympanomeatal flap (Vol. 2, Fig. **40**) for his one-stage fenestration of the horizontal canal, Lempert's endaural method soon spread throughout the world, popularizing the endaural operation. Shambaugh demonstrated that excision of the meatal skin was not necessary, using a long Surdille flap and extending the intertragal incision in a superior direction (Vol. 1, Figs. **50–54**). Lempert described a modification of the Surdille flap, which was attached to the upper edges of the tympanic membrane, by performing a circumferential incision in the posterior and superior meatal wall, and allowing the meatal skin, still attached to the drum, to be elevated in order to expose the tympanic cavity (Vol. 1, Figs. **54–57**) and then cover the attic region including the lateral semicircular canal.

Several other surgeons have improved endaural surgery procedures (Guns 1933, Lathorp 1943, Woodruff and Henney 1942, Tumarkin 1947).

Introducing tympanoplasty methods in the 1950s, Zöllner favored the endaural approach, in contrast to Wullstein, who used a retroauricular approach.

Techniques of Endaural Canal Wall–Down Surgery

As mentioned above, the cavities obtained with an endaural approach are generally small, and the procedure concentrates from the outset around the tympanic cavity, attic, and antrum. The mastoidectomy is performed only as far as is needed to eradicate the disease. The various endaural approaches, i. e., the Heermann II (Fig. **659**), Shambaugh (Fig. **660**), and

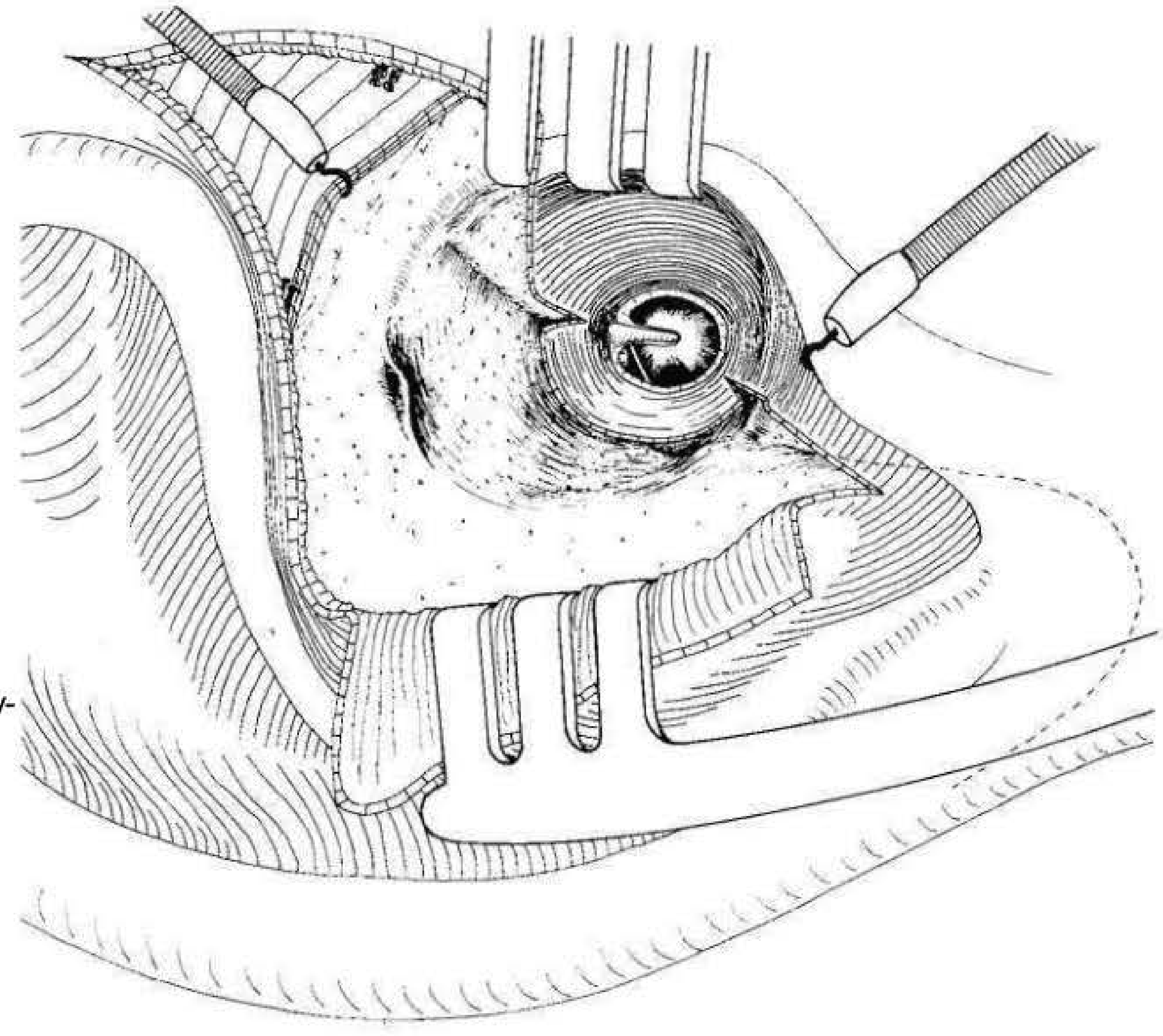


Fig. **659** **The Heermann II incision,** with elevation of the laterally-based skin flap of the posterior ear canal skin. A large tympanomeatal flap is created and the entire posterior half of the bony ear canal wall is exposed, as well as part of the mastoid plane. The dashed line indicates the position of the mastoid tip

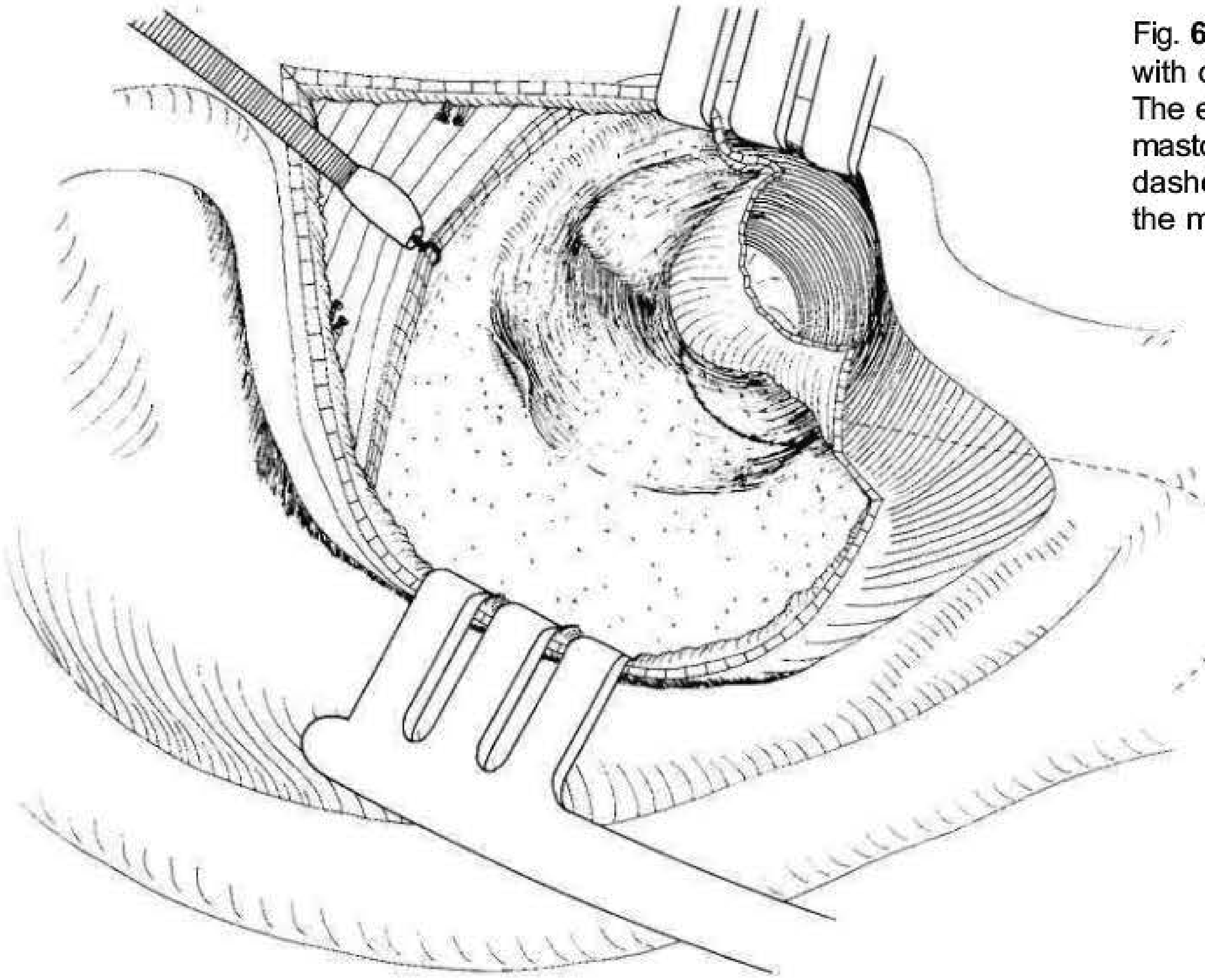


Fig. **660** **The Shambaugh incision,** with creation of a large Surdille flap. The ear canal far anteriorly and the mastoid plane are exposed. The dashed line indicates the extent of the mastoid tip

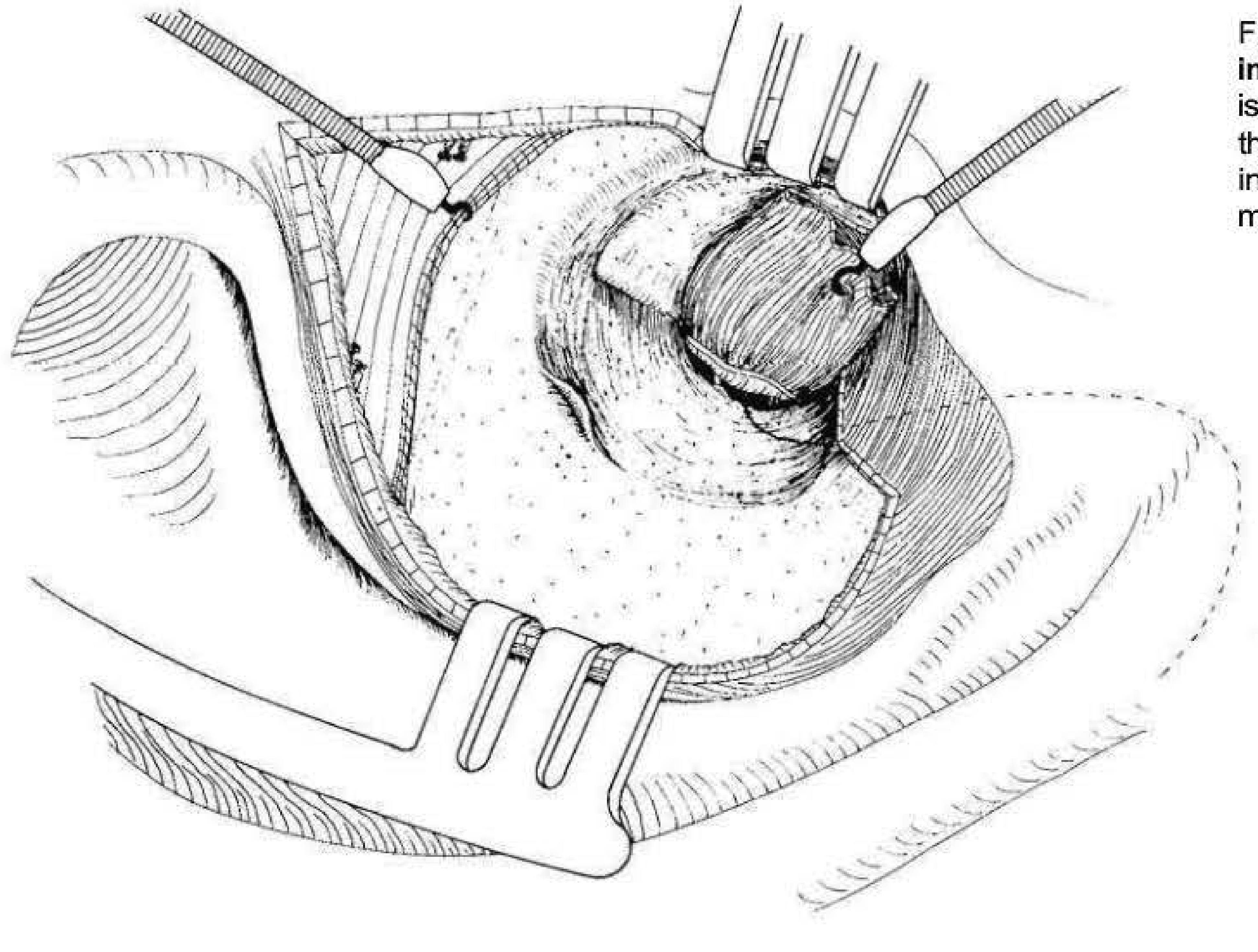
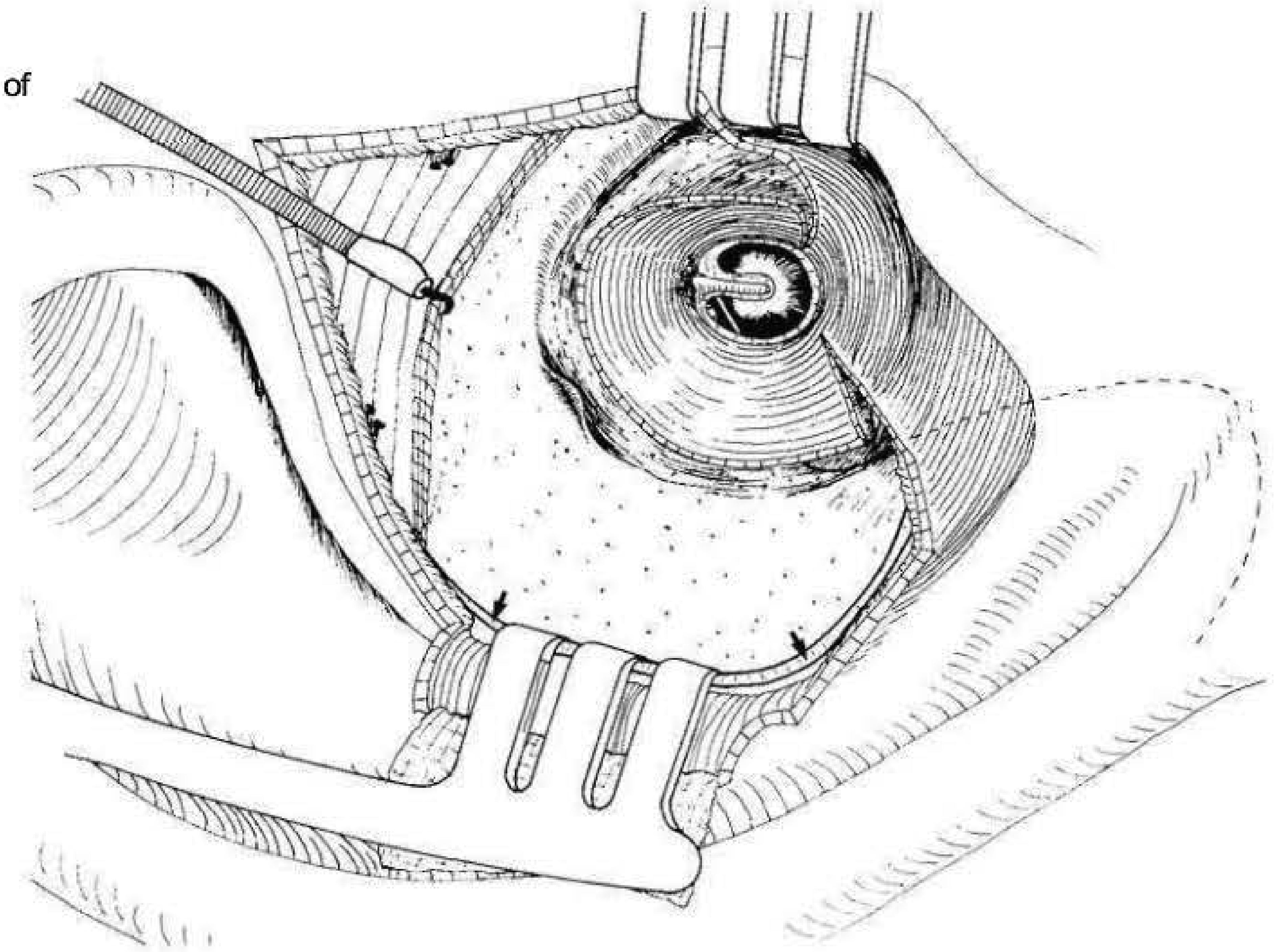


Fig. **661** **The Lempert incision.** The ear canal skin is elevated together with the drum. The dashed line indicates the extent of the mastoid tip

Lempert (Fig. **661**) incisions, permit exposure of a smaller area of the mastoid plane than the retroauricular approach. The mastoid tip is not accessible in any of these incisions. The Farrior incision (Fig. **662**), involving resection of the anterior edge of the conchal cartilage, and the Heermann III incision, extending around the auricle (Fig. **663**), enlarge the exposure of the mastoid plane and the access to the sinodural angle and the sigmoid sinus, but the mastoid tip is still not fully exposed. The cortical bone of the mastoid plane is not always removed in an endaural approach, and the pathology is followed in a posterior direction from the external auditory meatus (Fig. **664**), usually starting with widening of the ear canal, either from medial (inside-out) or from lateral (outside-in) and

Fig. **662** **The Farrior incision,** with excision of a strip of conchal cartilage (arrows) enlarging the access to the mastoid process



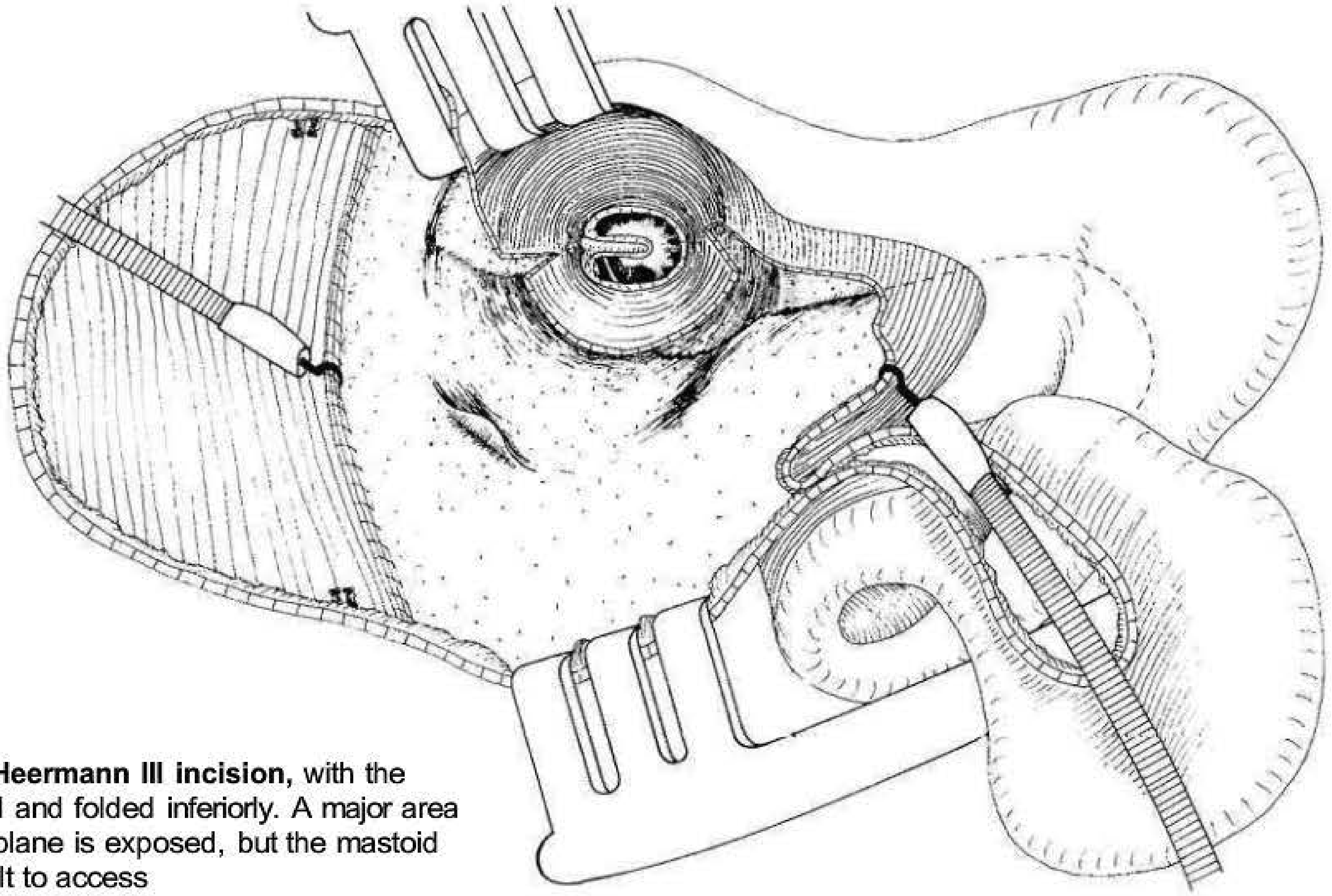


Fig. **663** **The Heermann III incision,** with the auricle elevated and folded inferiorly. A major area of the mastoid plane is exposed, but the mastoid tip is still difficult to access then continuing toward the attic and the antrum. The result may be a small atticoantrotomy or a larger canal wall–down mastoidectomy (Fig. **665**). The amount of cortical bone removed is still smaller in the most extensive endaural approach than in a retroauricular approach (Fig. **666**).

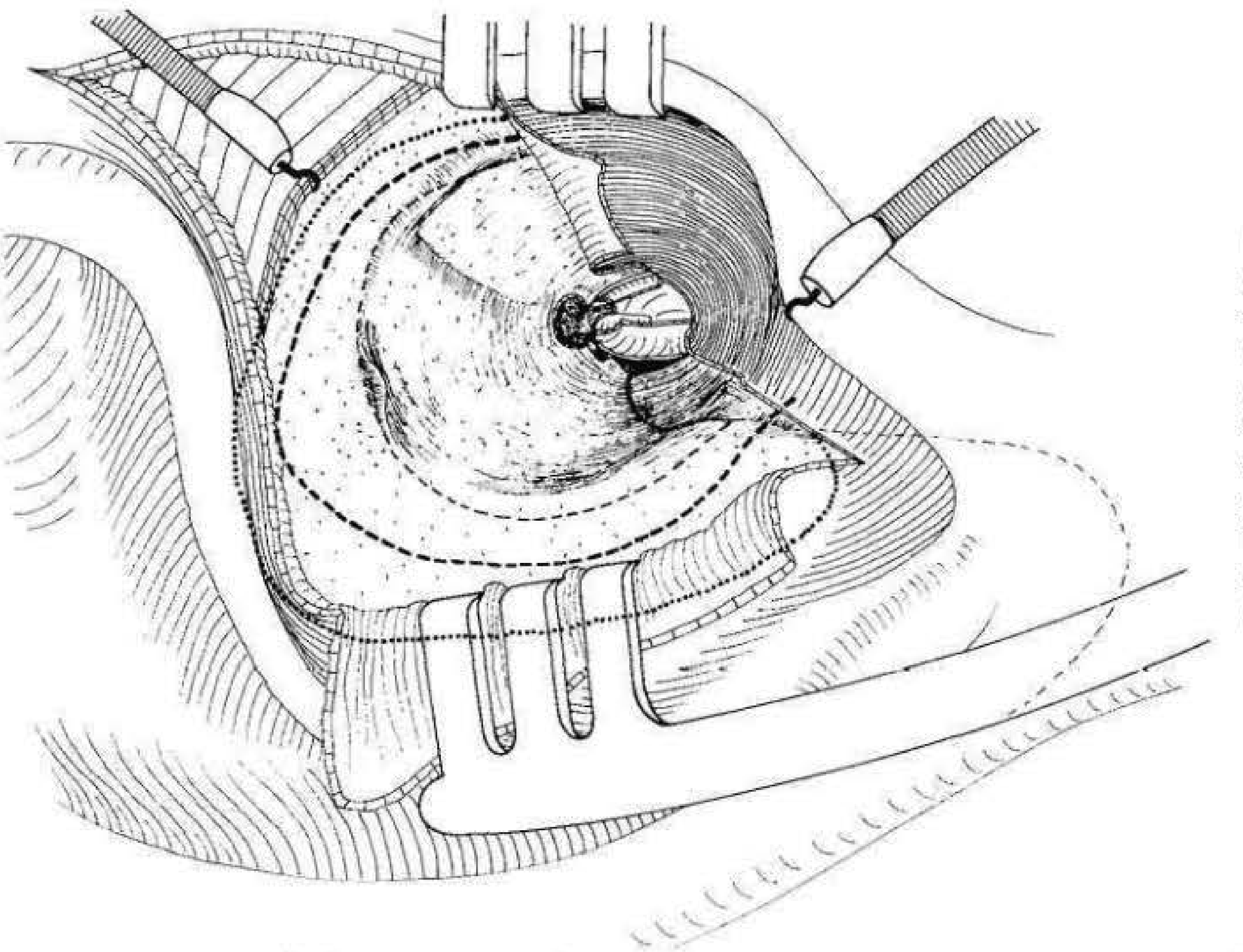


Fig. **664** **The extent of removal of the cortical bone of the mastoid plane in an endaural canal wall–down mastoidectomy:** no removal of the cortical bone at all (thin dashed line); some removal of the cortical bone, up to about 1 cm posterior to the suprameatal spine (thick dashed line); extensive removal of the cortical bone, requiring further retraction of the auricle (dotted line)

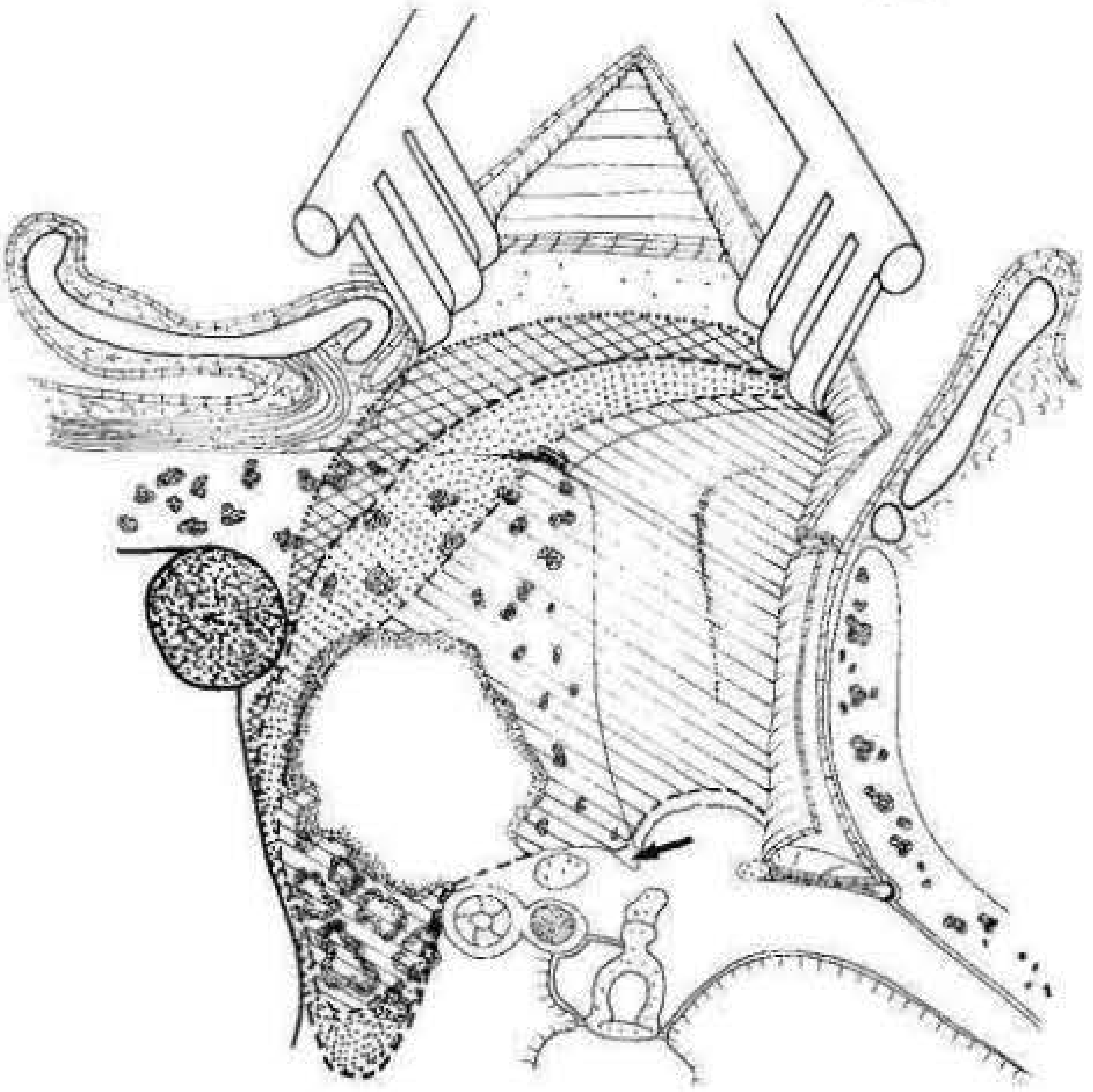


Fig. **665** **Resection of the cortical bone of the mastoid plane, seen in a side view.** The bone from the ear canal and the edge of the mastoid plane is removed, resulting in a small atticoantrotomy (hatched area). Some resection of the cortical bone of the mastoid plane, allowing access to the posterior fossa dural plate and the sigmoid sinus (dotted area). Extensive removal of the cortical bone and the mastoid plane, providing sufficient exposure of the sigmoid sinus and posterior fossa dural plate (double-hatched area). Arrow: bony annulus

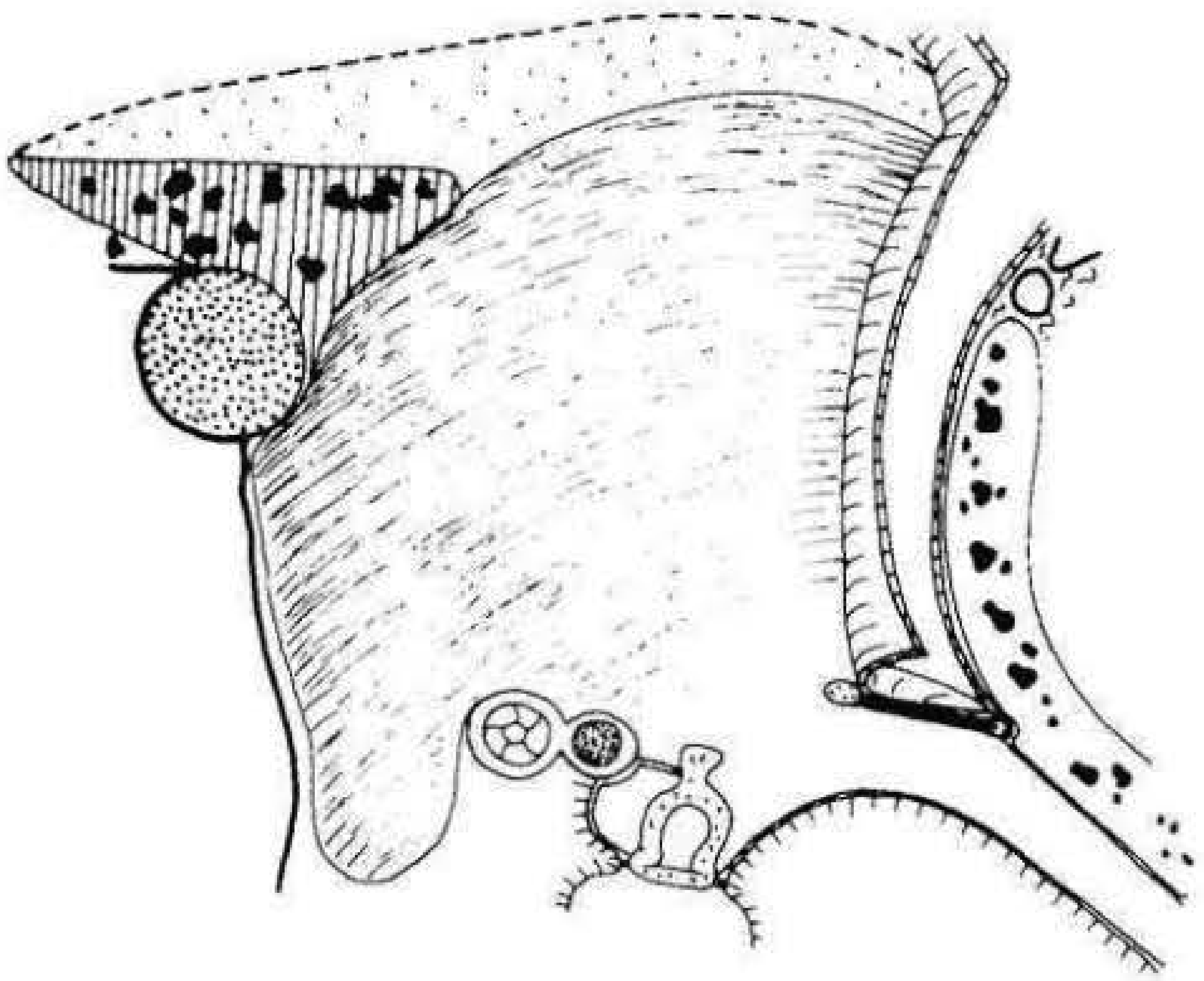


Fig. **666** The dotted area of the cortical bone of the mastoid plane, indicating the difference between bone removal in the retroauricular approach and the endaural approach

Techniques with Removal of the Bridge

When performing endaural canal wall–down mastoidectomy, the present author prefers the inside-out route, starting, after initial widening of the bony ear canal, with a posterior tympanotomy and otosclerosis drilling, providing early information about the condition of the ossicular chain (Fig. **667**). If the ossicular chain is defective, further drilling can be rapidly and safely performed. The lateral attic wall is removed posterosuperiorly, providing information about the malleus head and the position of the middle fossa dural plate at the tegmen antri. Further drilling in a posterior direction opens the antrum (Fig. **668**) and lowers the facial ridge. The drilling continues along the middle fossa dural plate, polishing it and ensuring that all air cells and bony overhangs are removed. The transition from the anterior bony ear canal wall over the zygomatic root to the mastoid tegmen should be smooth, so that epithelialization of the cavity can take place. Usually there are no problems in removing all pathology from the attic, the tegmen tympani, and the mastoid tegmen, because reasonable exposure of the superior part of the cavity is possible through the endaural approach (Figs. **659–662**).

Posterosuperiorly, the drilling is extended to the sinodural angle, which is cleaned. The view to the sigmoid sinus may be difficult in cases with extensive pneumatization (Fig. **669**). Drilling toward the

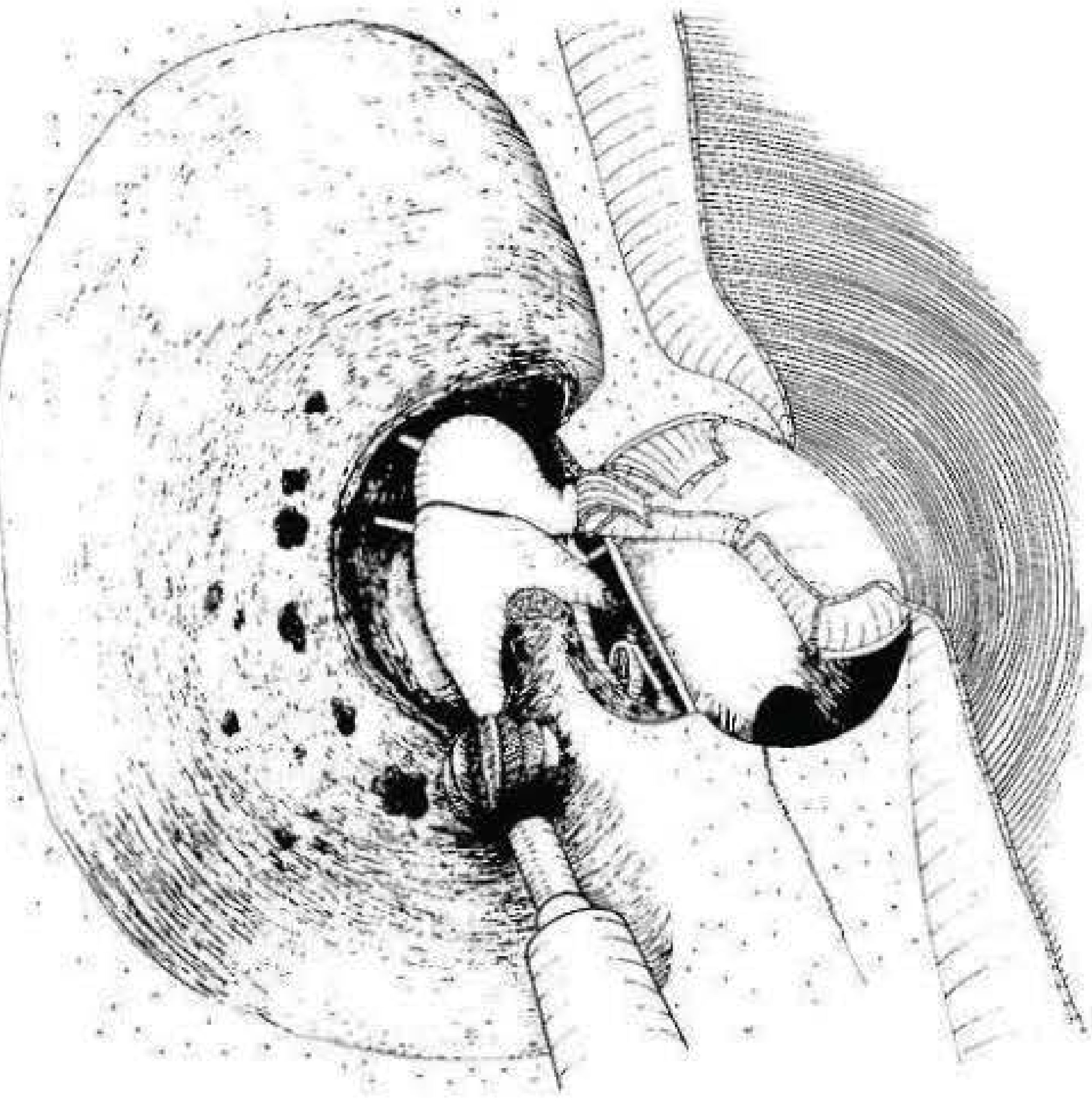


Fig. **667** **Endaural canal wall–down mastoidectomy,** starting with enlargement of the bony ear canal, posterior tympanotomy, otosclerosis drilling, and removal of the lateral attic wall, exposing the malleus and the defective incus. The atticotomy is completed, and the drilling continues towards the antrum

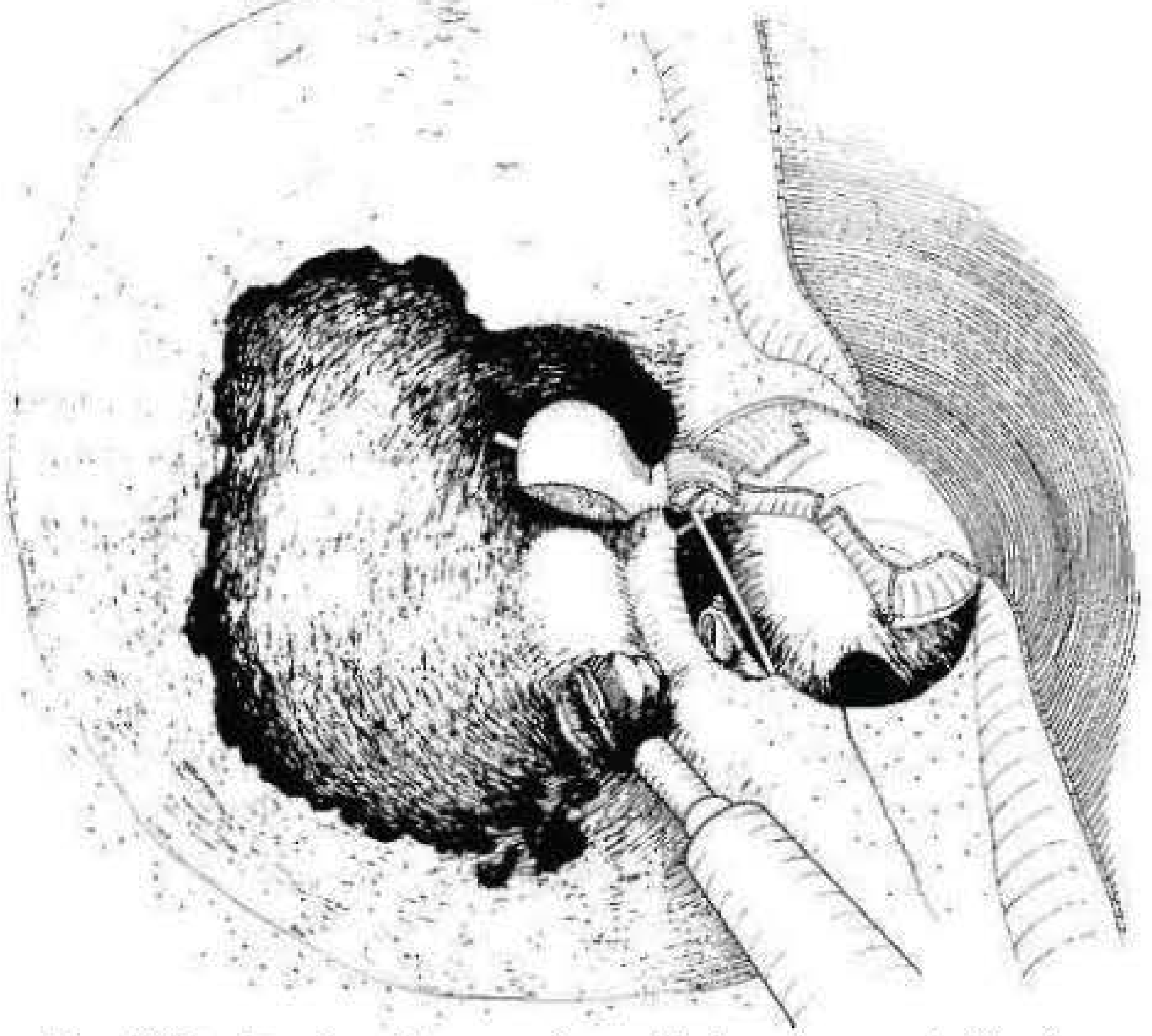


Fig. **668** Endaural canal wall–down mastoidectomy continues in a posterior direction, with opening of the antrum and lowering of the facial ridge. The defective incus is removed. The mastoid air cells are exenterated toward the mastoid tip

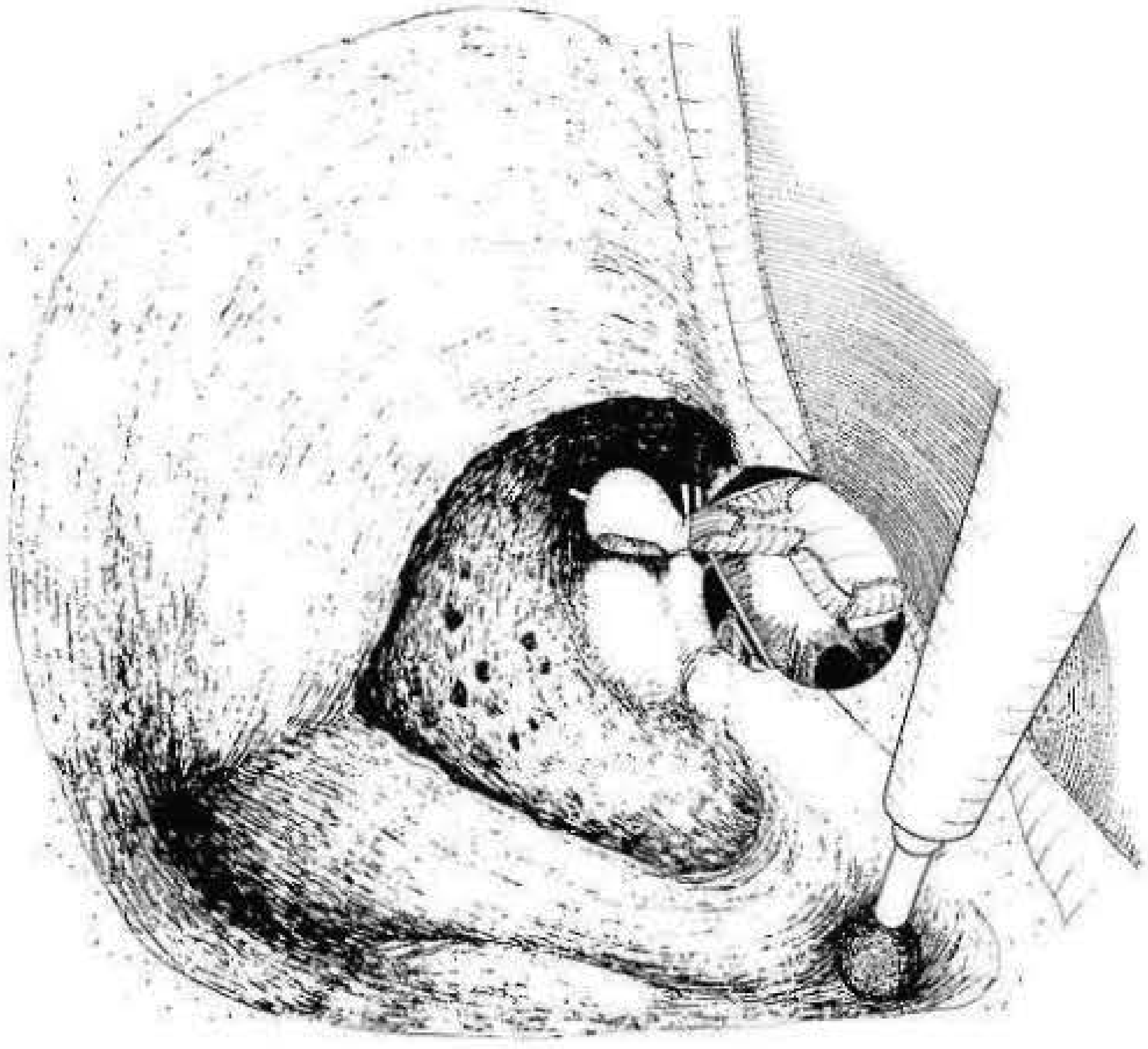


Fig. **669** Endaural canal wall–down mastoidectomy is completed, the cavity is created, the superior wall of the cavity is polished, the sinus wall is cleaned, and the sigmoid sinus is localized. Inferiorly the cavity is small and the facial ridge goes straight down towards the facial nerve. If needed the cavity can be further enlarged towards the mastoid tip mastoid tip may also prove difficult in cases with extensive pneumatization. The facial ridge is usually low, but can be further lowered to the level of the facial nerve if necessary, due to the extension of the cavity toward the mastoid tip.

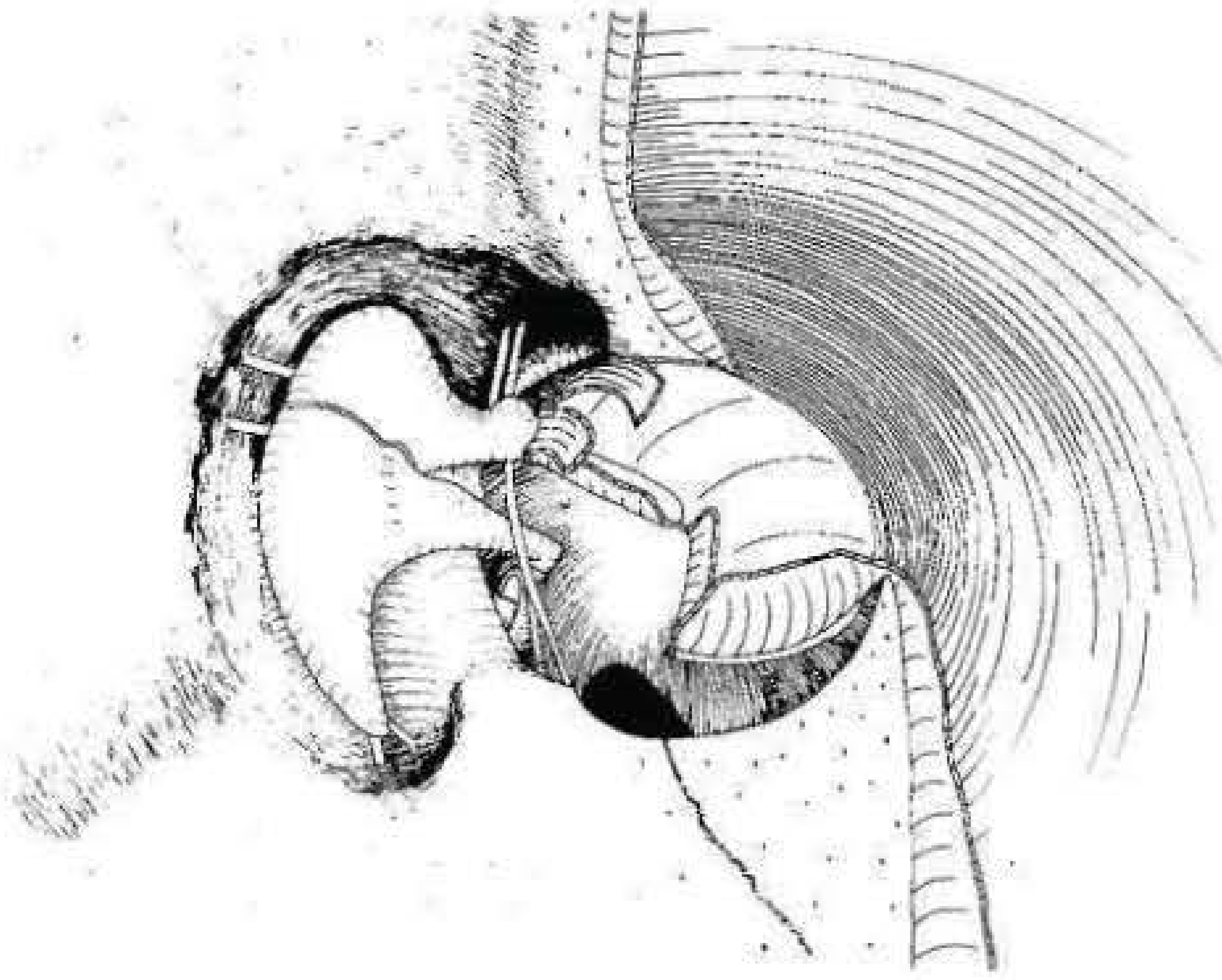


Fig. **670** The situation after a small endaural cavity in a case with an intact ossicular chain and posterior perforation. The facial ridge is low, the cavity walls are smooth, and the attic can be ventilated. There is good access to the anterior tympanum, and the the Eustachian tube orifice and anterior attic are cleaned. There is also a good view of the tympanic sinuses posteriorly

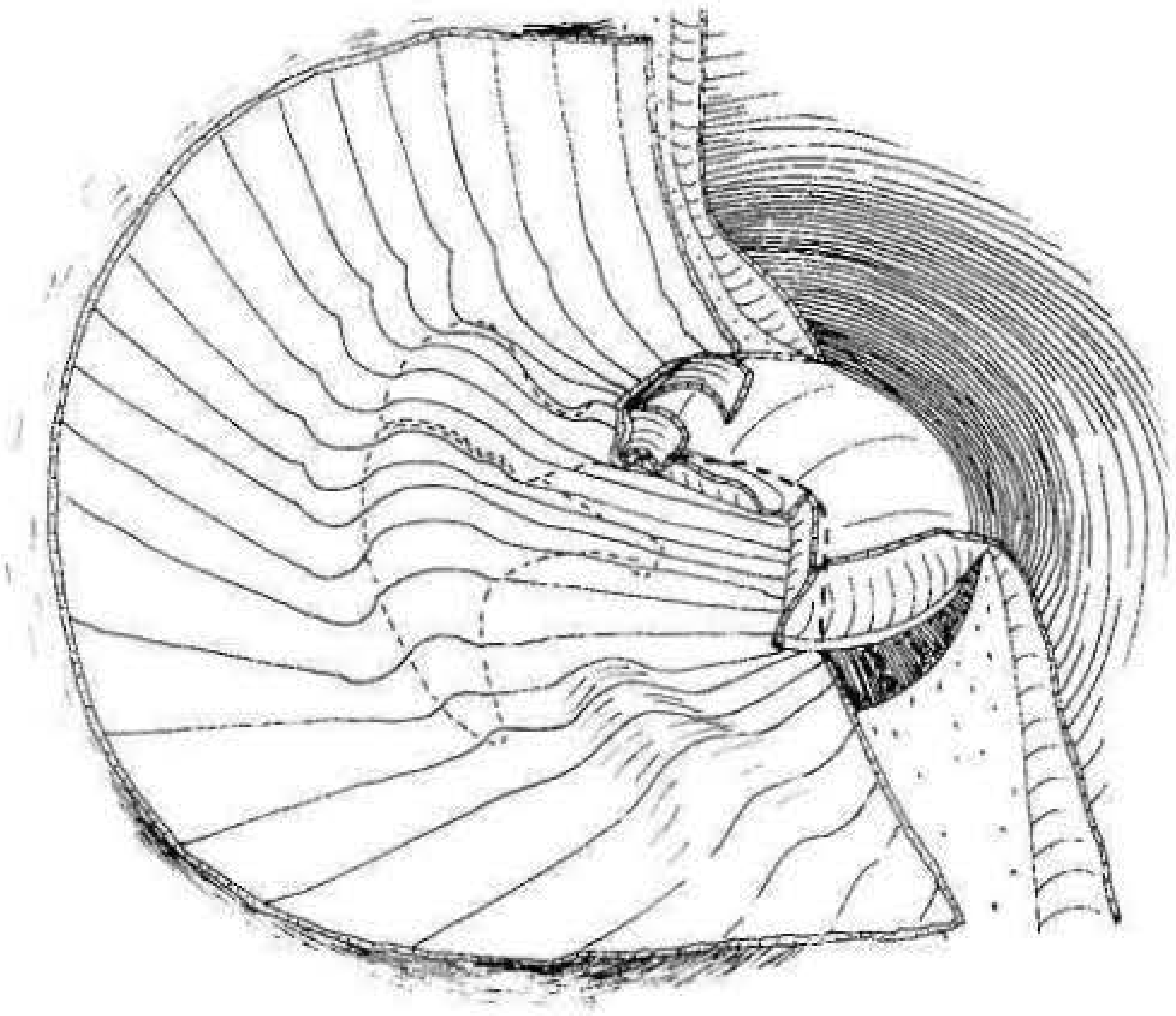


Fig. **671** **Reconstruction of an endaural cavity with an intact ossicular chain.** The fascia is created as an underlay graft, covering the facial ridge, the ossicular chain, and the mastoid tegmen. Ventilation of the attic can take place, but the antrum region is intended to be an open cavity

Reconstructions in Cases with No Bridge

In ears with no bridge, the resulting cavity is usually an open cavity, at least in the attic region. The chance of achieving a dry cavity after an endaural canal wall–down mastoidectomy without obliteration is good, because the cavity is small and the access created by the endaural approach is large; in addition, all the skin flaps are preserved, i. e., the laterally-based skin flap in the Heermann (Fig. **659**) and Farrior incisions (Fig. **662**), or the large, medially-based Surdille flap in the Shambaugh (Fig. **660**) and Lempert incisions (Fig. **662**). These skin flaps can be further shaped either into a large, inferomedially-based flap to cover the facial ridge, or a large, anterosuperiorly-based flap to cover the medial and superior walls of the cavity.

Many variations are possible to cover the lateral parts of the endaural cavity, and these depend upon the incision used. Reconstruction of the medial part of the cavity depends on the remaining ossicular chain and drum remnant.

Intact ossicular chain. In cases with an intact ossicular chain and missing bridge (Fig. **670**), repneumatization of the attic is desired. A large fascial graft is placed as an underlay graft under the drum remnant, covering the ossicles and continuing to the tegmen antri. Inferiorly, it covers the facial ridge (Fig. **671**). After replacement of the skin flaps, epithelialization of the fascia and the cavity is promoted (Fig. **672**), and the attic is capable of being pneumatized, resulting in good hearing (Fig. **673**). The rest of the cavity remains either open, with fascia or skin flaps covering the bone, or can be obliterated.

Missing incus, stapes present. In cases with a defective incus, but with the malleus head and stapedial arch present (Fig. **674**), autogenous incus (Fig. **675**) or a piece of cortical bone is usually interposed between the stapes and the malleus handle. The fascia, as underlay graft, covers the ear drum perforation, the interposed incus, the malleus head, and the lateral semicircular canal, as well as the medial wall of the cavity and the facial ridge (Fig. **675**). After the flaps have been replaced, rapid epithelization of the medial cavity wall takes place (Fig. **676**). Pneumatization of the anterior attic is either maintained (Fig. **677**), or the fascia retracts around the malleus head, but even in such cases the malleus may remain mobile (Fig. **678**). Retraction around the malleus head in cases with an open attic does not represent a risk of a deep retraction pocket or cholesteatoma formation.

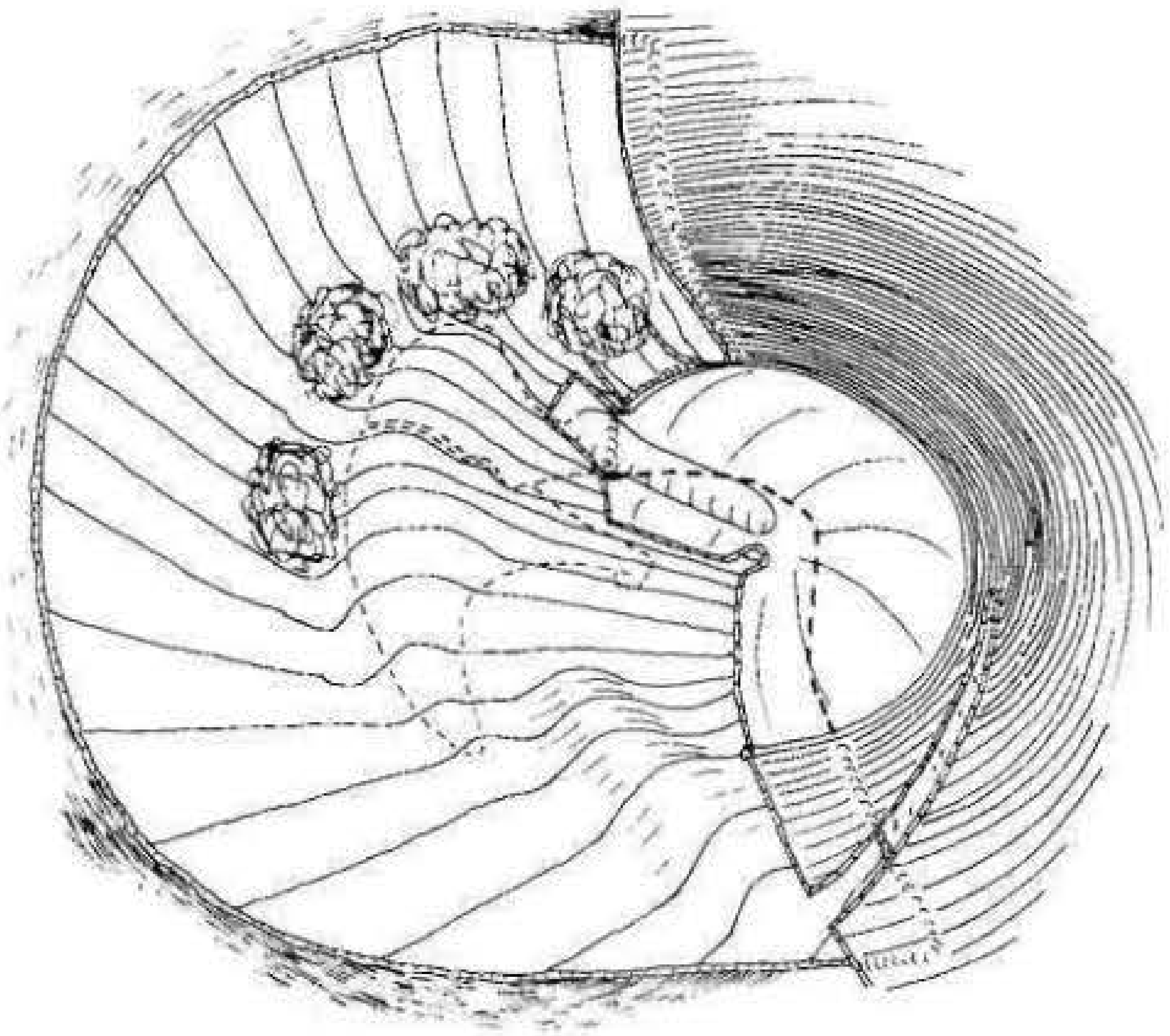


Fig. **672** The canal skin flaps are replaced, and the fascia is fixed at the tegmen tympani, allowing ventilation of the attic

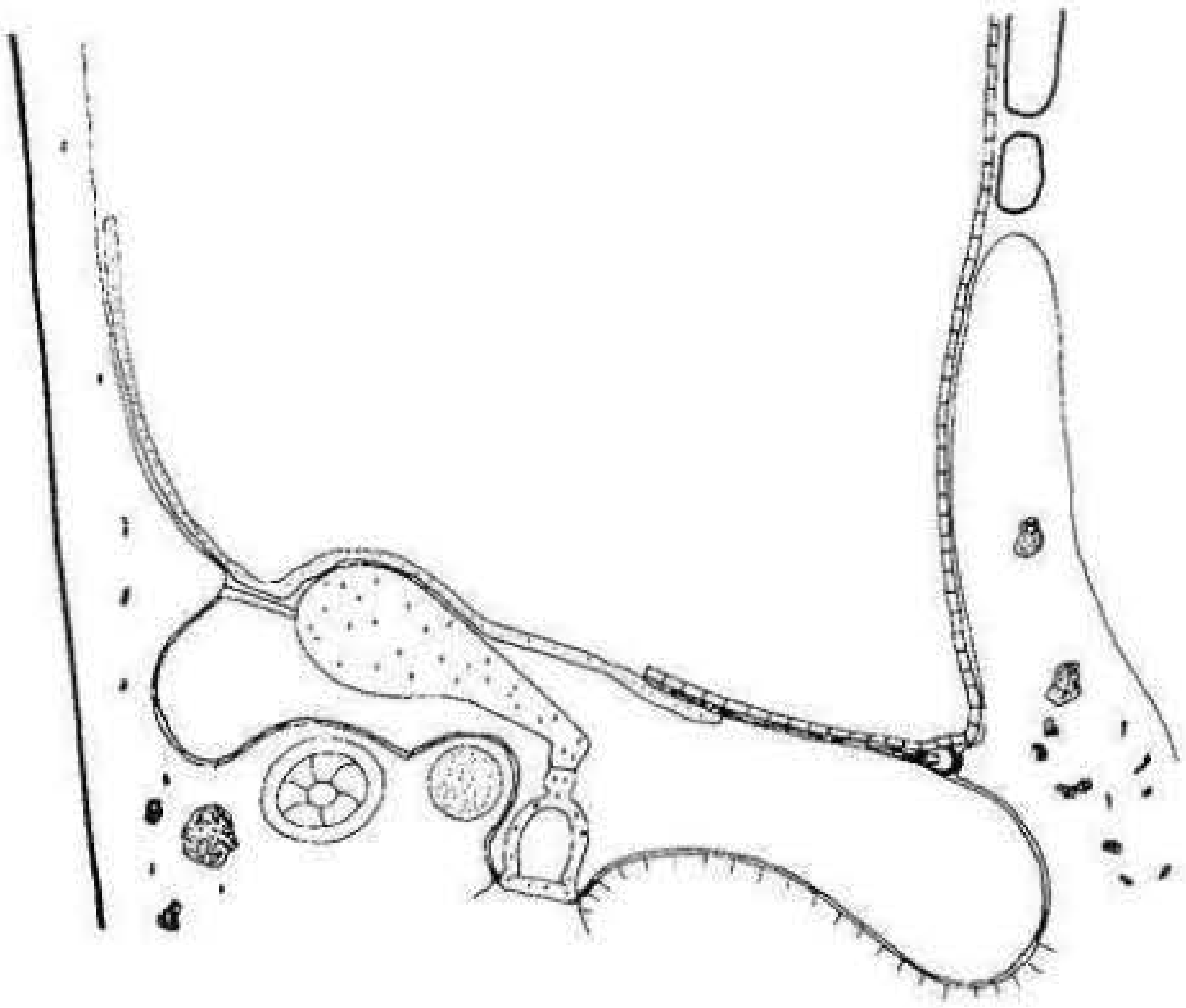


Fig. **673** Side view of the reconstructed endaural cavity, with a ventilated attic at the level of the incus, illustrating the placement of the fascia

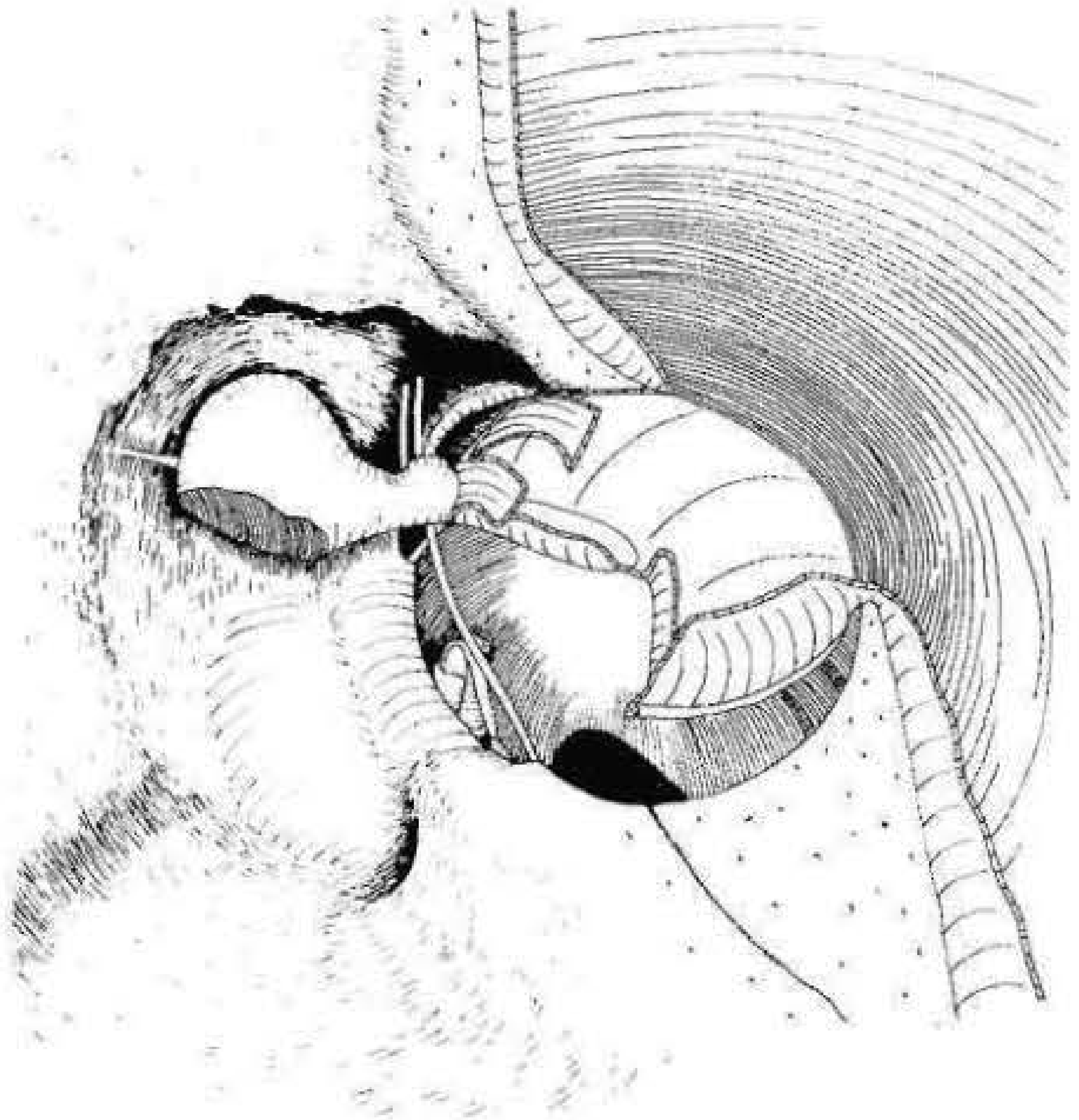


Fig. **674** The cavity after an endaural canal wall–down mastoidectomy, with the incus body removed and a posterior perforation of the pars tensa. The cavity wails are polished, except for the anterior attic, and ventilation can take place here, with an excellent view of the anterior attic and the sinuses

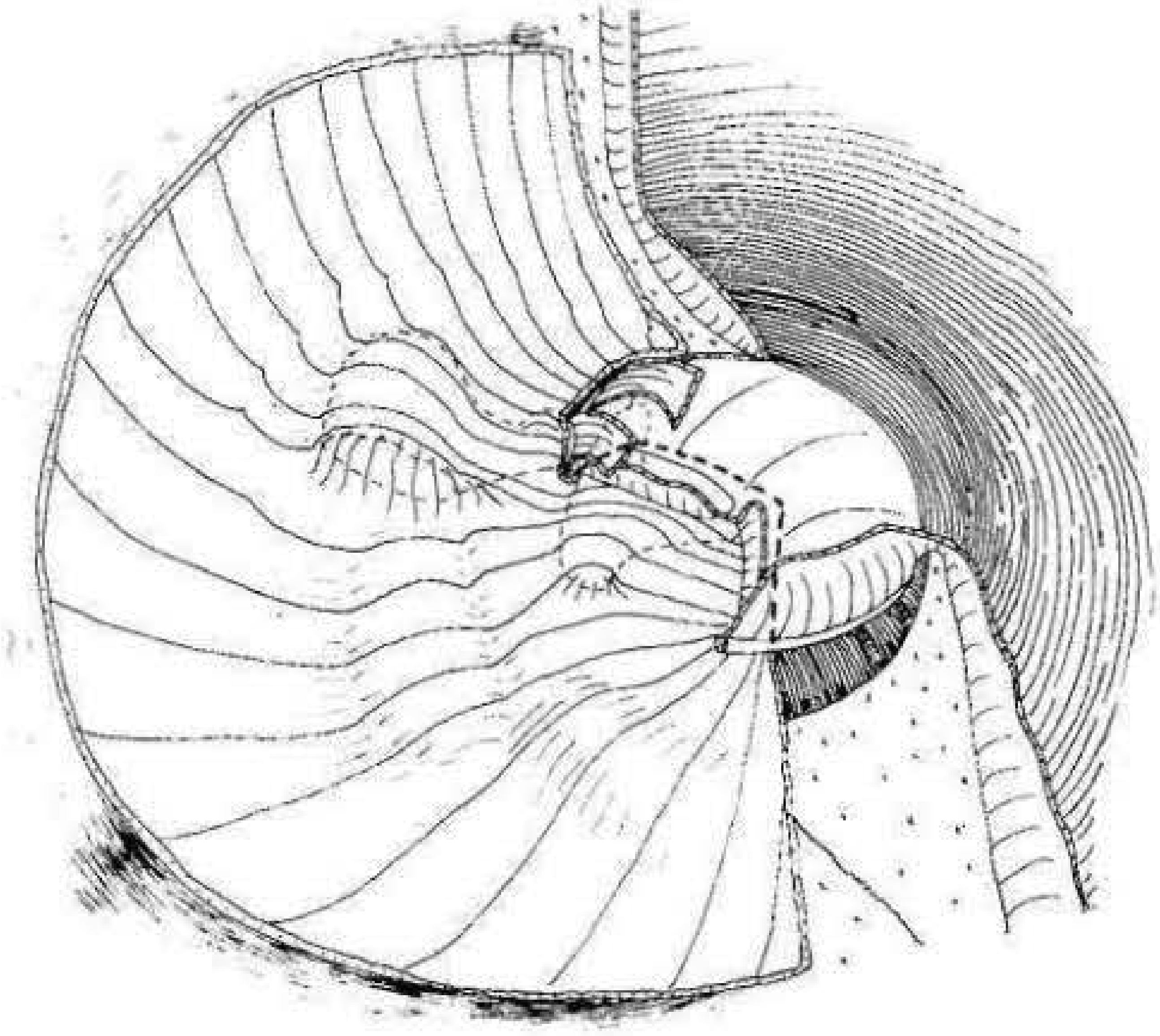


Fig. **675** **Reconstruction of the cavity after interposition of the incus** between the head of the stapes and the malleus handle, placing the fascia as an underlay graft. The fascia covers the head of the malleus, allowing ventilation of the anterior attic, but in the posterior attic, the fascia goes medially onto the lateral semicircular canal and the facial ridge. The posterior attic is not ventilated

Missing incus and malleus head. This situation with an intact stapes is common in attic cholesteatoma (Fig. **679**). The malleus head has been resected because of severe erosion due to cholesteatoma. After interposition with an incus, autogenous cortical bone, or tragal cartilage between the stapes and the malleus (Fig. **680**), a large fascial graft covers the ear drum defect, the medial wall of the cavity, the tegmen antri, and the facial ridge (Fig. **681**). The cavity is safe, with no risk of retraction, and sometimes the

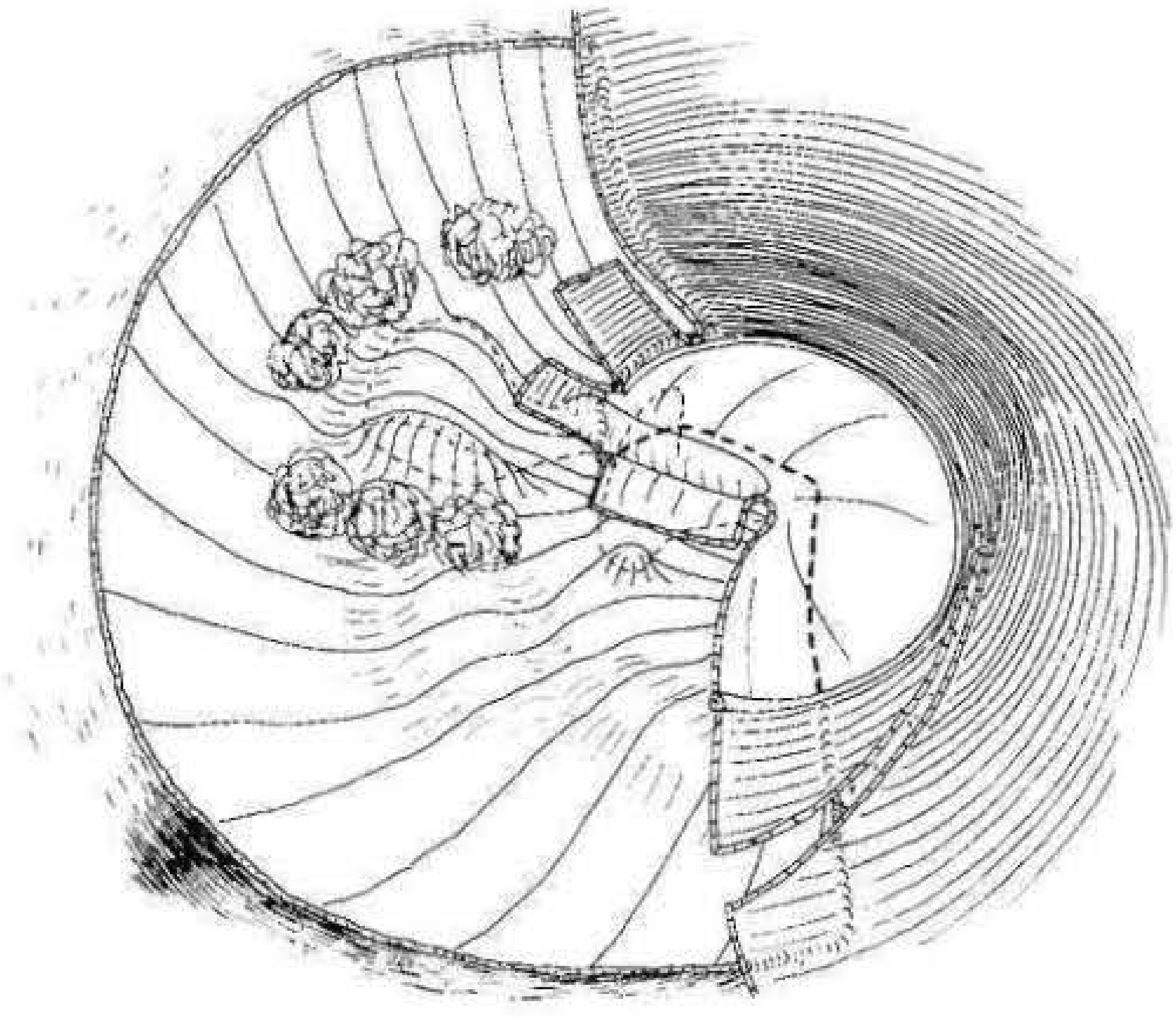


Fig. **676** The skin flaps are replaced, and Gelfoam is fixing the fascial graft

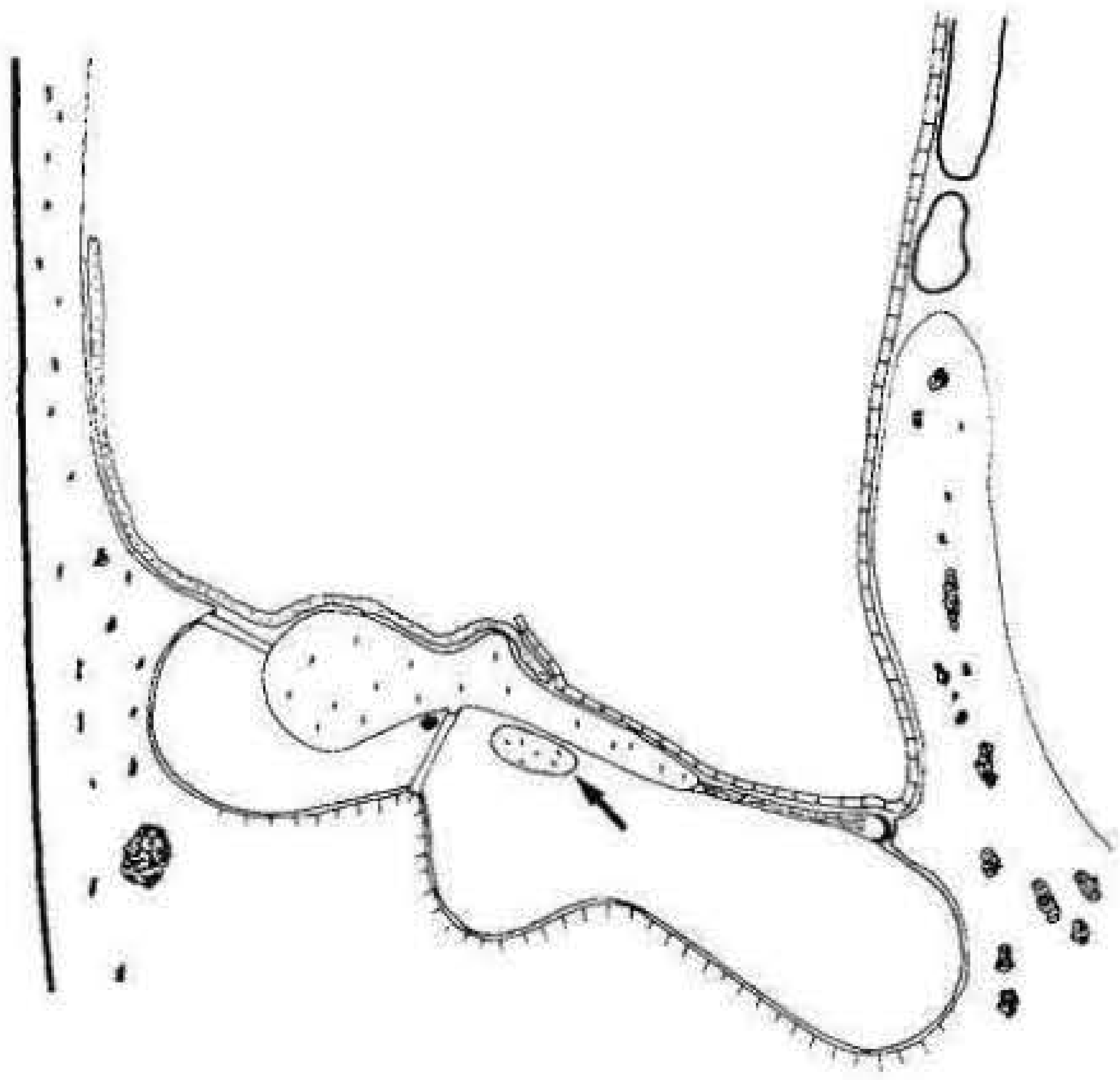


Fig. **677** Side view of the reconstruction of a small cavity, with the malleus head present and an interposed incus with the short process under the malleus (arrow). The fascia covers the head of the malleus and the tegmen tympani. The anterior attic is ventilated

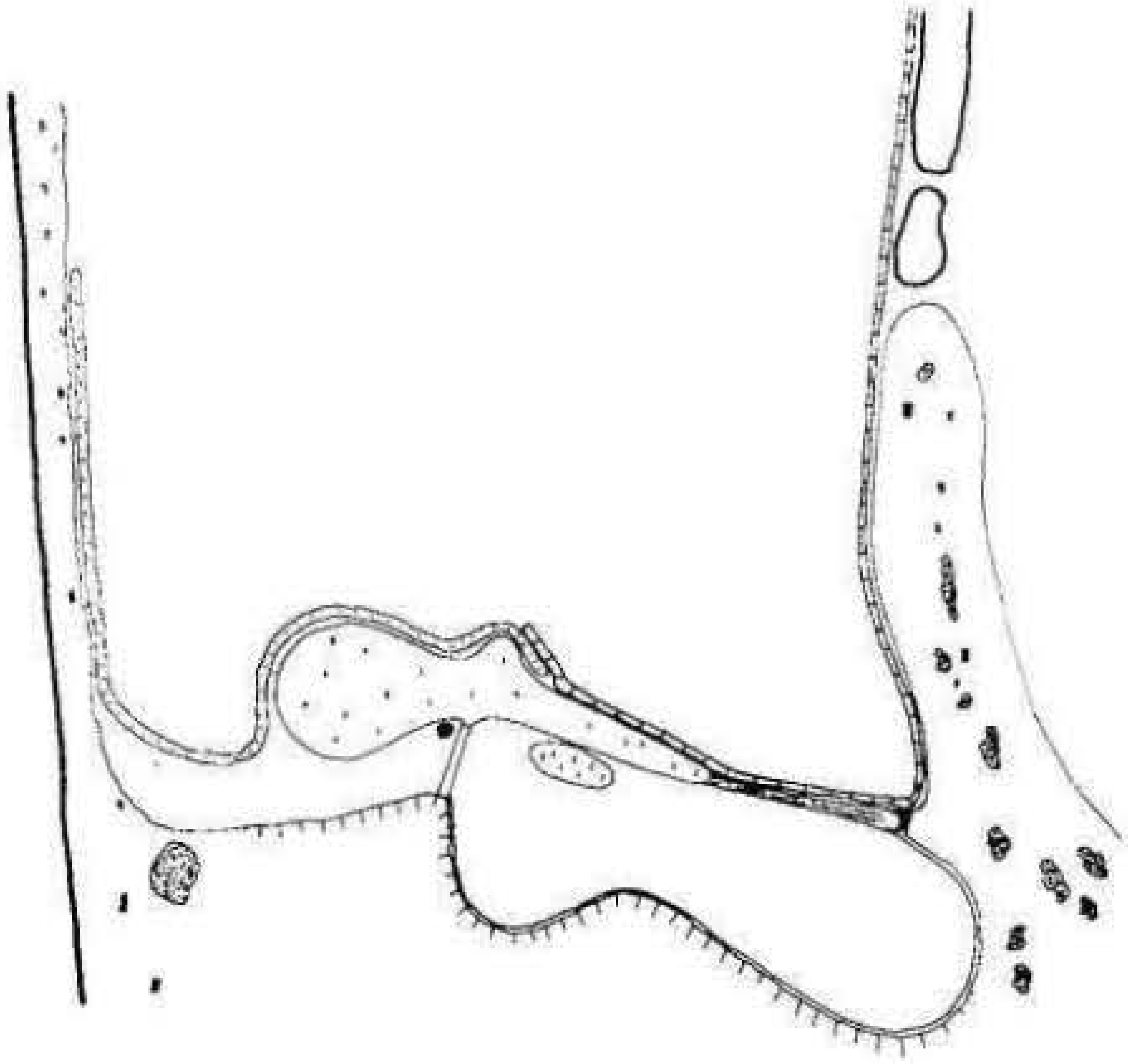


Fig. **678** A similar situation to that in Fig. **677**, but with the fascia going around the malleus head

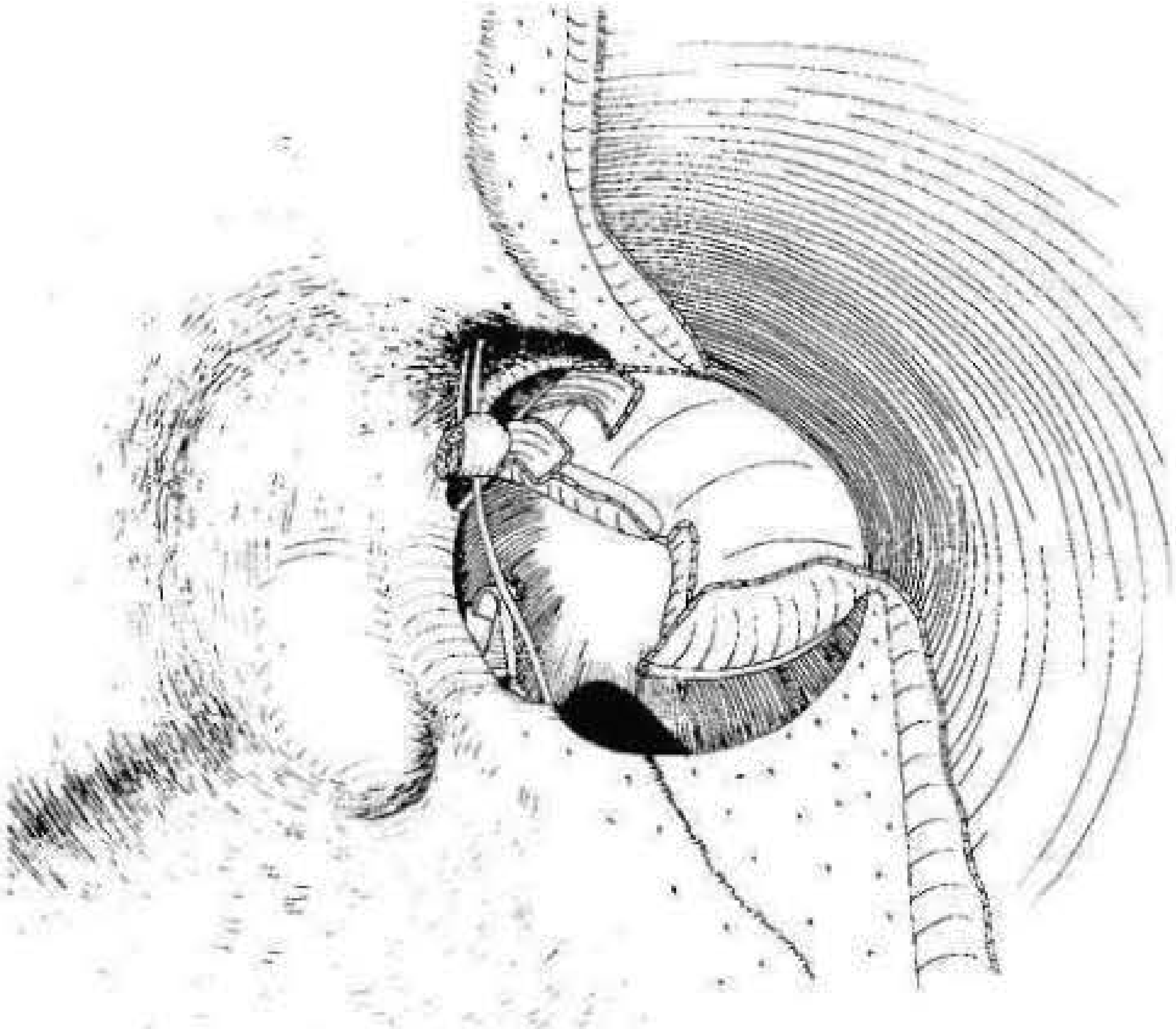


Fig. **679** Situation after endaural canal wall–down mastoidectomy in a case of removal of the incus and resection of the malleus head. The attic is open, the walls of the cavity are polished all the way around, and the attic will remain as an open cavity. There is a good view of the anterior attic resulting function can be quite good (Fig. **682**). In cases with a missing stapedial arch and malleus head, a columella, autogenous incus remnant, or L-shaped columella made of cortical bone, are usually used (Fig. **683**). The reconstruction with fascia is the same as shown previously (Figs. **680–683**), but the functional results are much poorer than in ears with the stapes present.

Missing entire malleus and incus. In ears with a missing incus and malleus handle, but with the

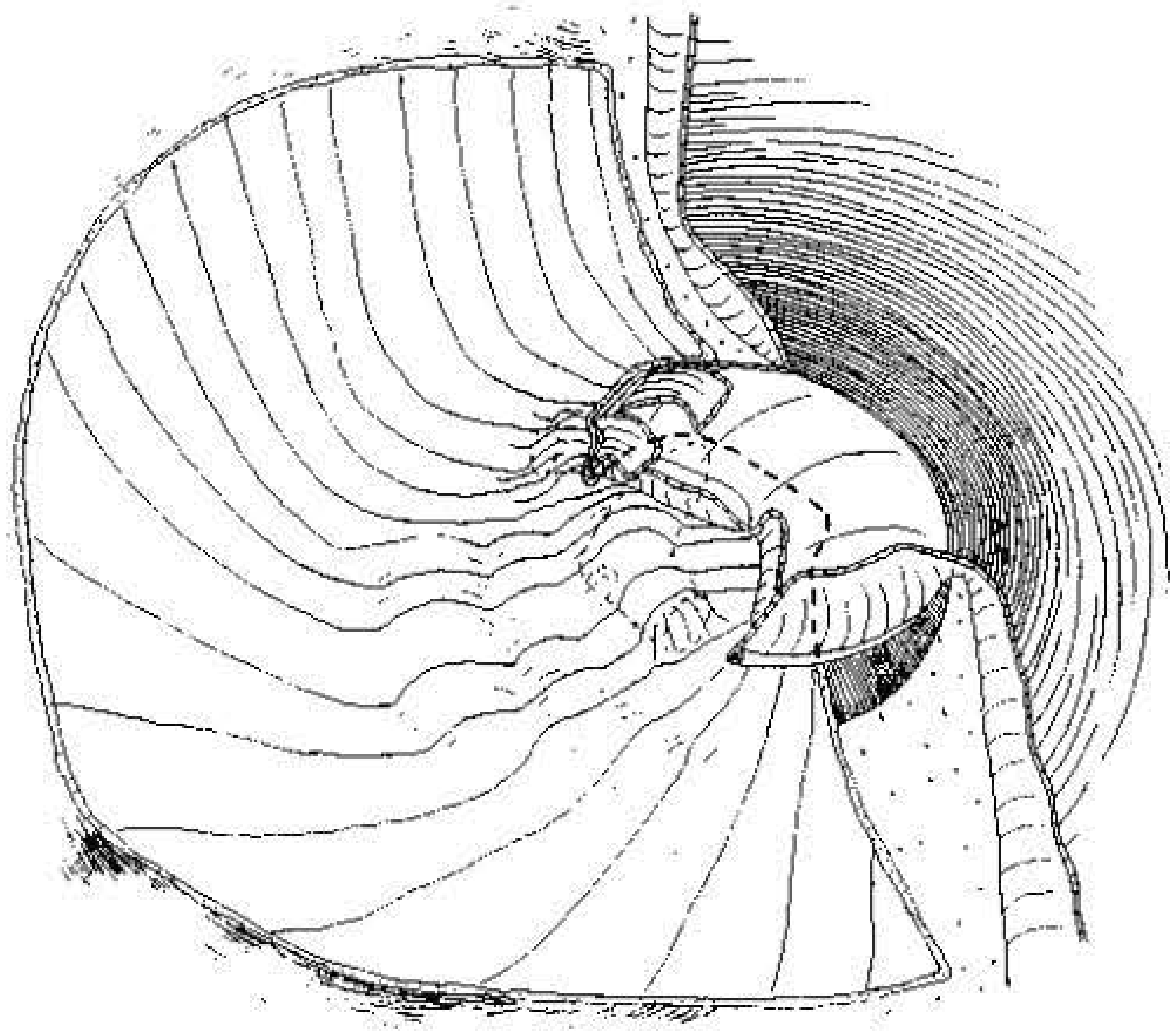


Fig. **680** **Reconstruction of the cavity in a case with a missing malleus head,** with the incus interposed between the head of the stapes and malleus handle and the fascia placed as an underlay graft under the drum remnant but on the neck of the malleus. A fascial graft covers the medial wall of the attic, the prominence of the lateral semicircular canal, and the facial ridge, as well as the mastoid tegmen

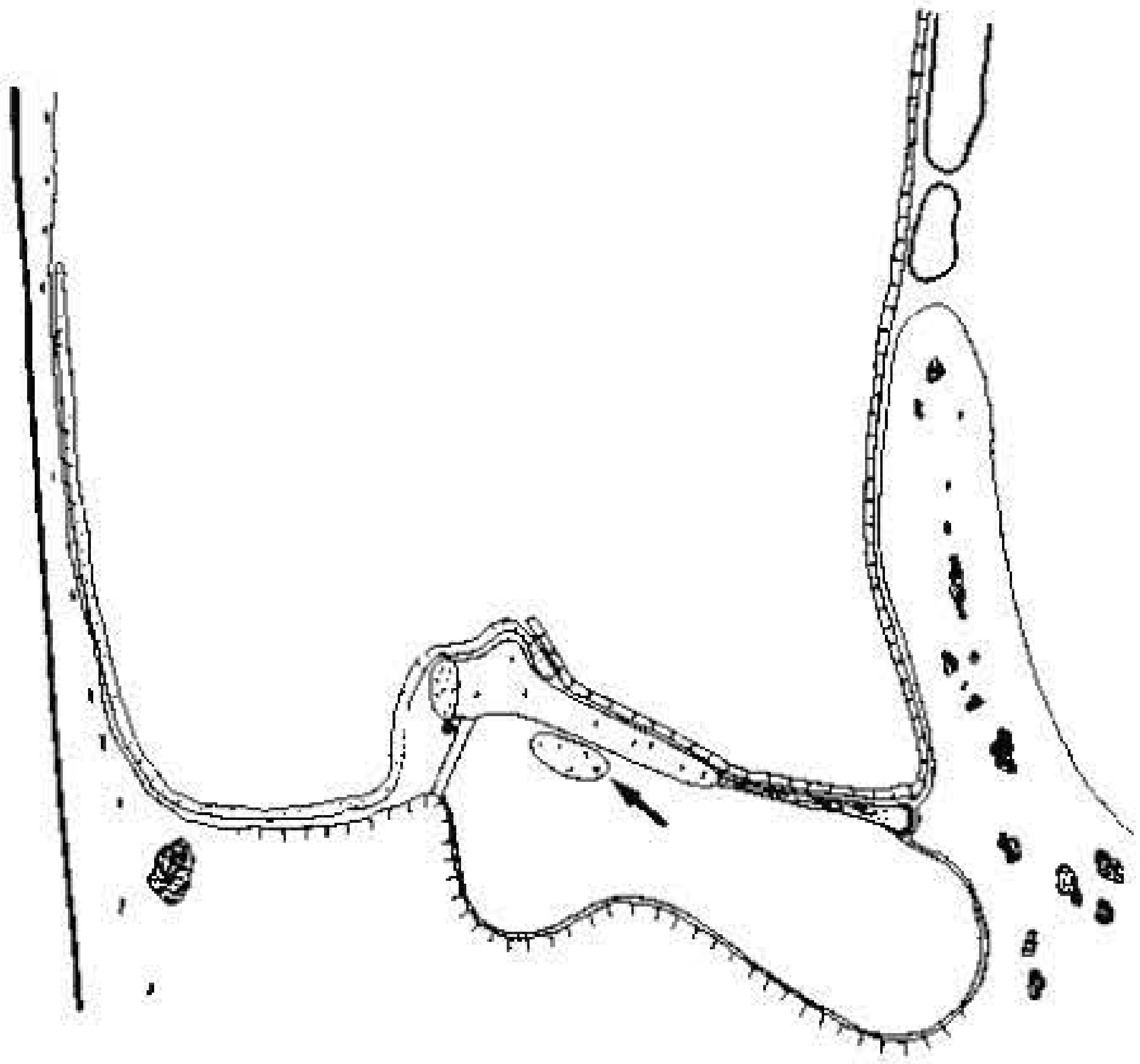


Fig. **682** Side view of the reconstructed tympanic cavity with the incus interposed and the short process of the incus placed under the malleus handle (arrow). The fascia covers the neck of the malleus and the medial wall of the attic, which is an open cavity

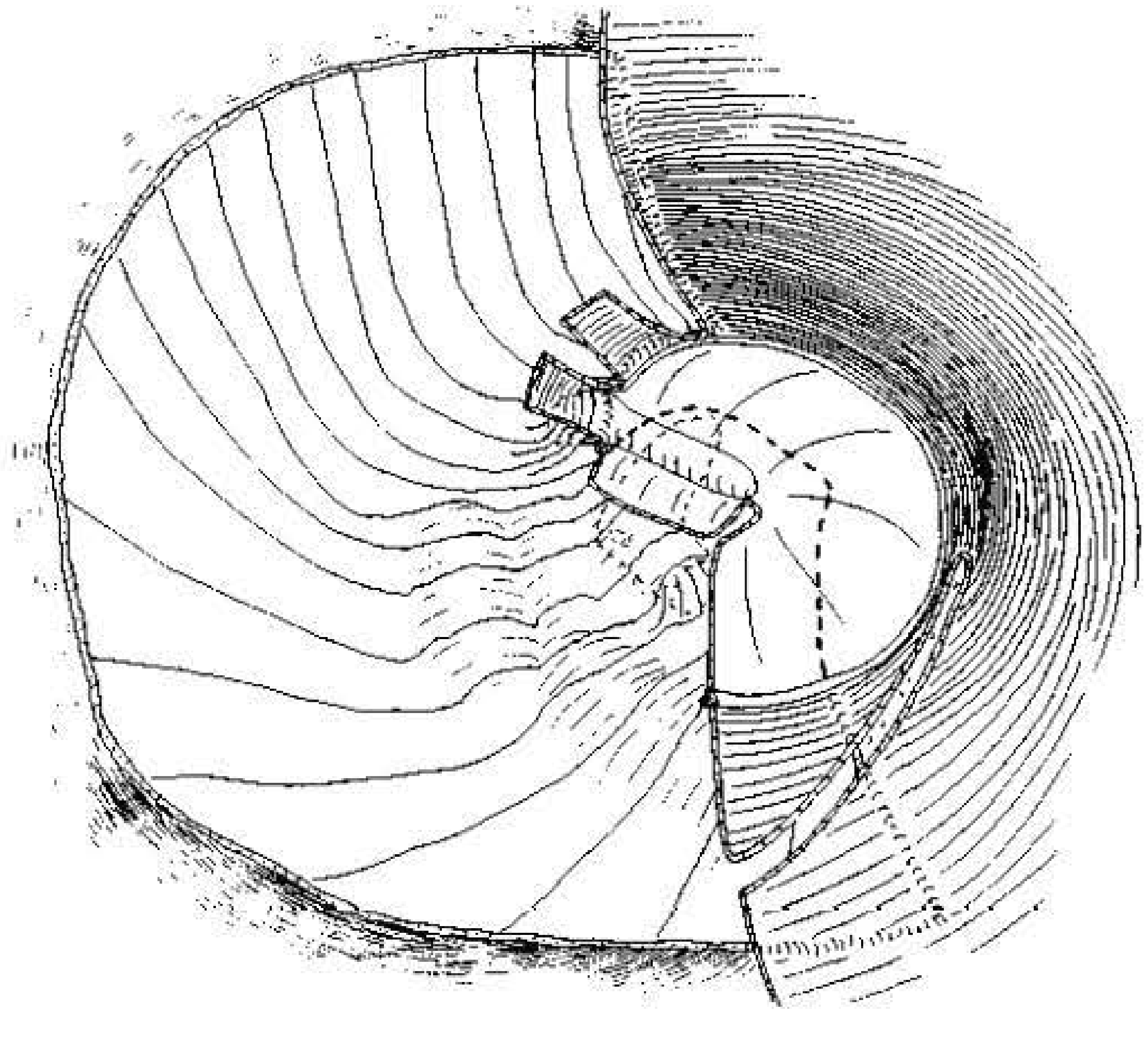


Fig. **681** The skin flaps are replaced

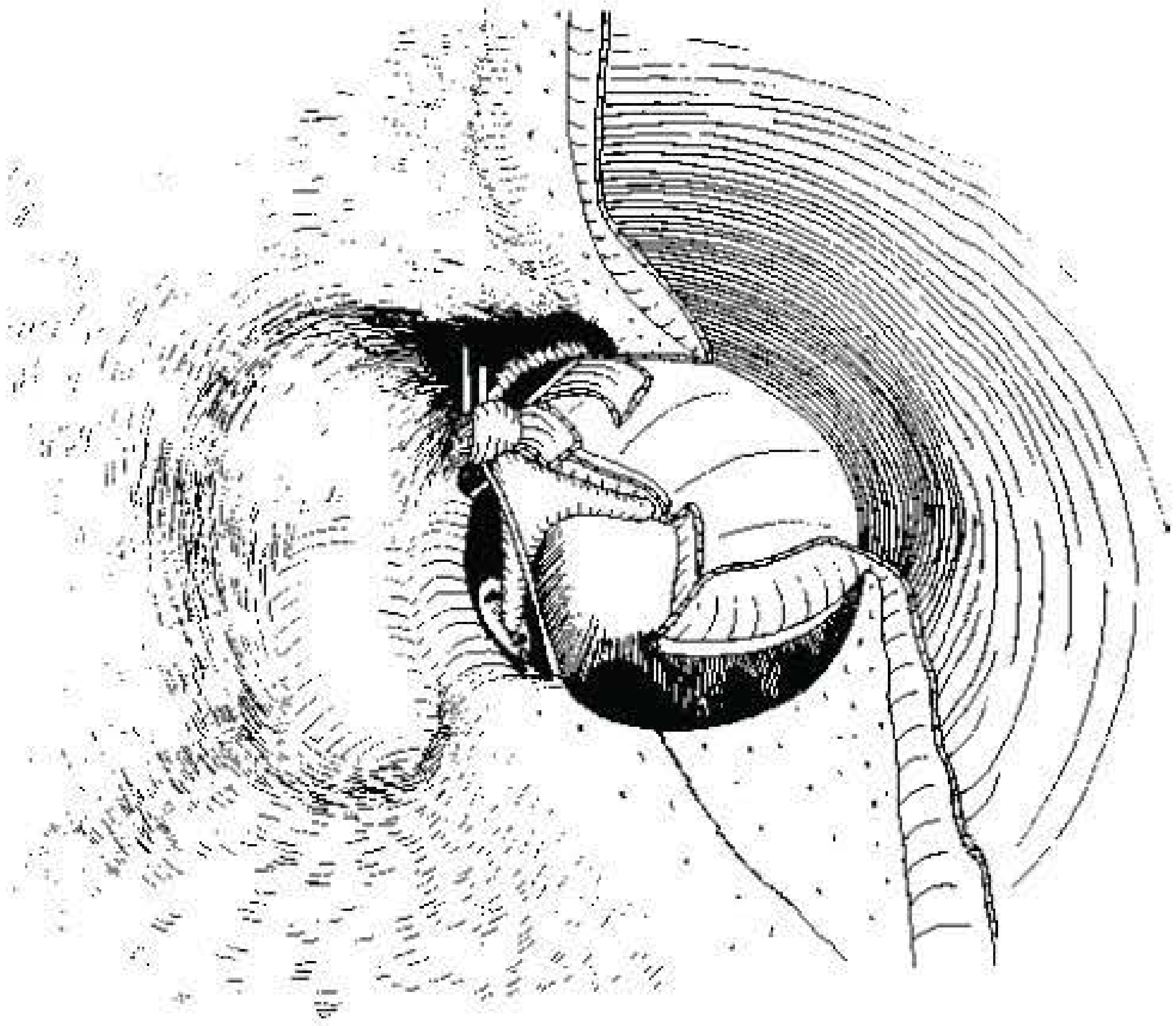


Fig. **683** A similar situation to that in Fig. 679, but the stapedial arch is missing and the ossiculoplasty is performed with an L-shaped piece of cortical bone columella, placed parallel to the malleus handle

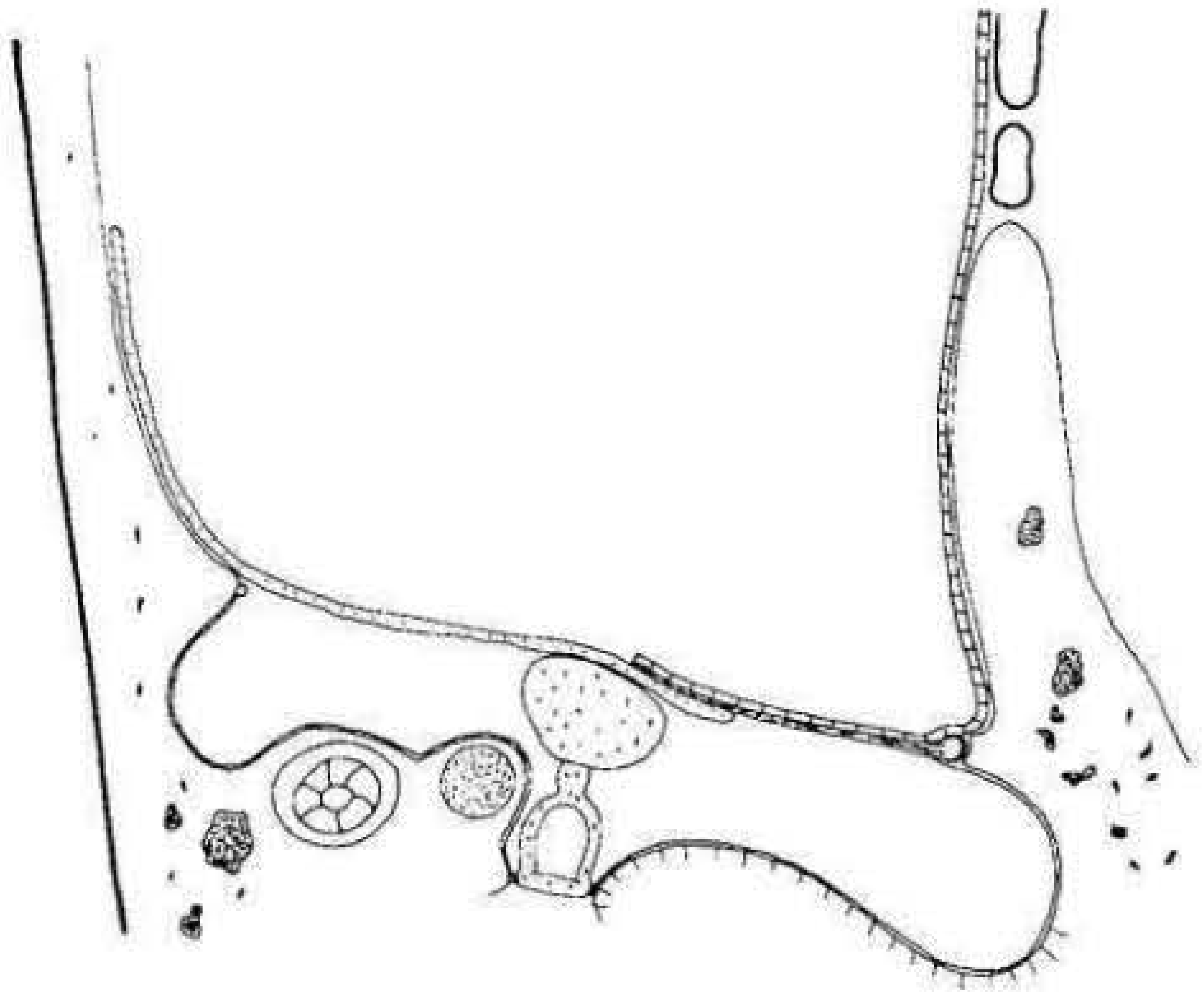


Fig. **684** **Reconstruction of the endaural canal wall–down mastoidectomy in a case with no malleus and incus, but with the stapes present.** A bone graft is placed on the capitulum, and the fascia is fixed to the tegmen tympani, in the hope that ventilation of the empty attic will take place

stapes present, e. g., in tensa retraction cholesteatoma and in cases where the malleus handle has been removed, an autogenous incus remnant or cortical bone can be placed on the stapes head, and the attic possibly repneumatized (Fig. **684**). Retraction onto the medial wall of the attic will not cause deep retraction pockets. The fascia is usually placed as an underlay graft on the incus and the medial wall of the attic, also covering the tegmen tympani and antri (Fig. **685**). In ears in which exenteration of deep perilabyrinthine cells has resulted in a deep groove between the tegmen tympani and the lateral or even superior semicircular canals, fascia either covers the groove, in the hope of migration and self-cleansing (Fig. **686**), or the groove can be obliterated (Fig. **687**).

No ossicles. In cases with a missing malleus, incus, and stapedial arch, an L-shaped columella of cortical bone or an autogenous incus remnant is placed on the footplate (Fig. **688**). Fascia, as an underlay graft, covers the columella and the medial wall of the attic, as well as the tegmen tympani and antri. The resulting tympanic cavity is small, and the functional results are usually poor.

In some cases, a type IV tympanoplasty is recommended (Fig. **689**). The round window niche is protected by placing the fascia as an onlay graft on the fibrous annulus, thus ventilating the hypotympanum (Vol. 1, Figs. **1083–1092**). A large fascial

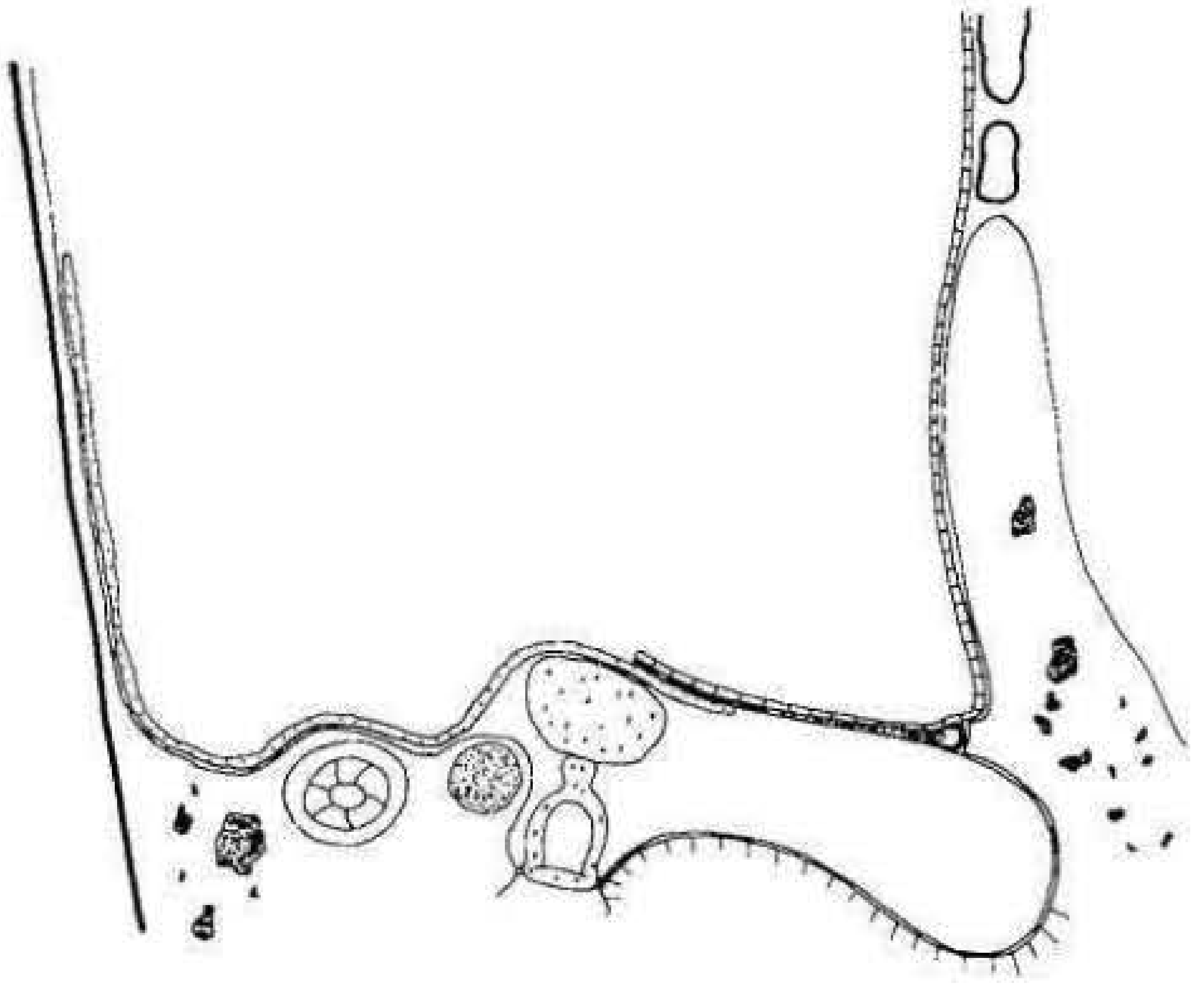


Fig. **685** Reconstruction of a similar situation to that in Fig. **684** with the fascia placed on the medial wall of the attic, with no ventilation

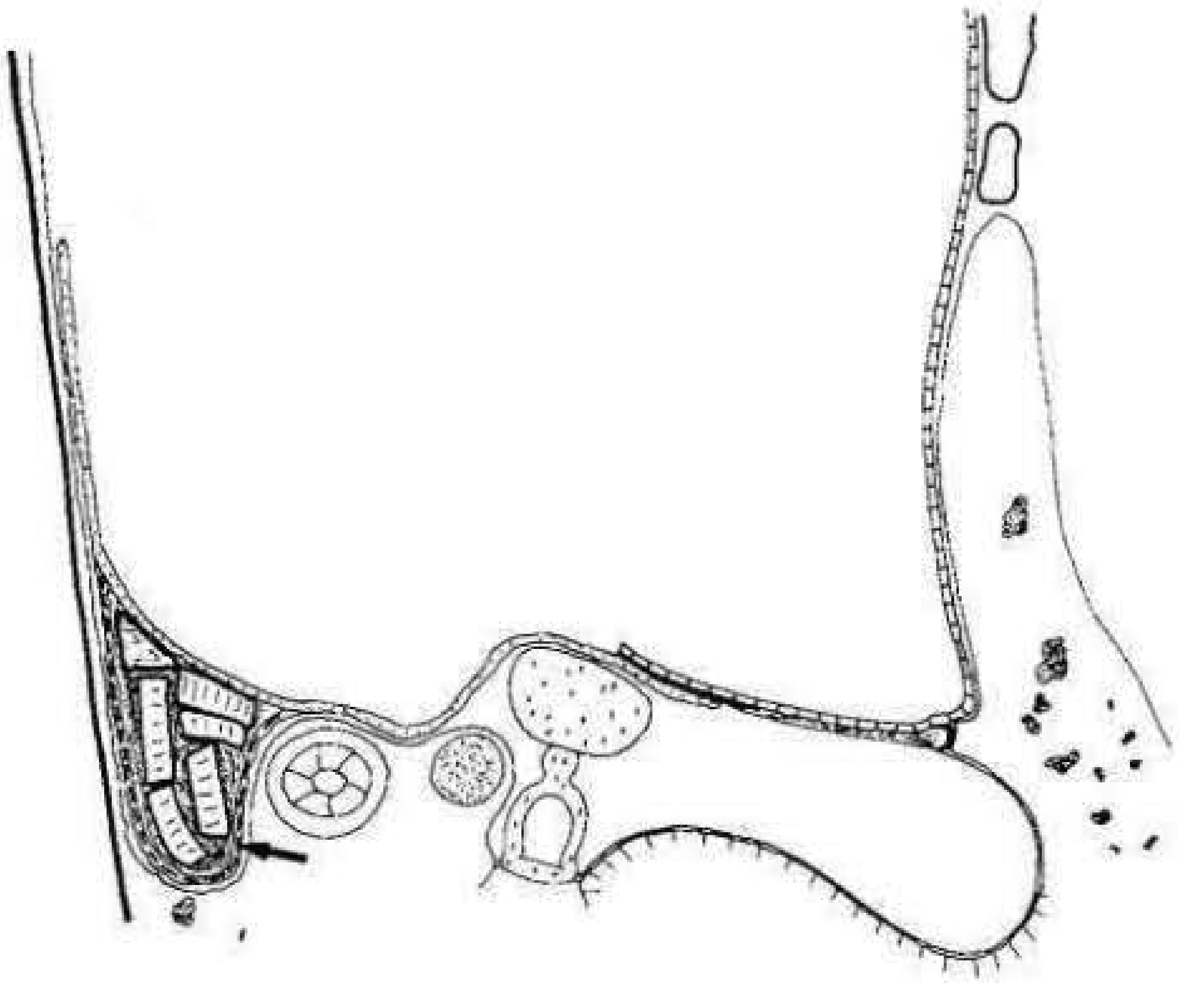


Fig. **686** **Partial obliteration of the attic after an endaural canal wall–down mastoidectomy.** In a similar situation to that in Fig. **685**, after exenteration of the perilabyrinthine cells, a deep groove, is obliterated with small pieces of tragal cartilage attached to perichondrium. The attic is covered with a fascia continuing onto the tegmen tympani. If there is no obliteration, the fascia is placed on the bone, leaving the groove as an open cavity. The alternative position of the fascia graft is illustrated with a dashed line and an arrow

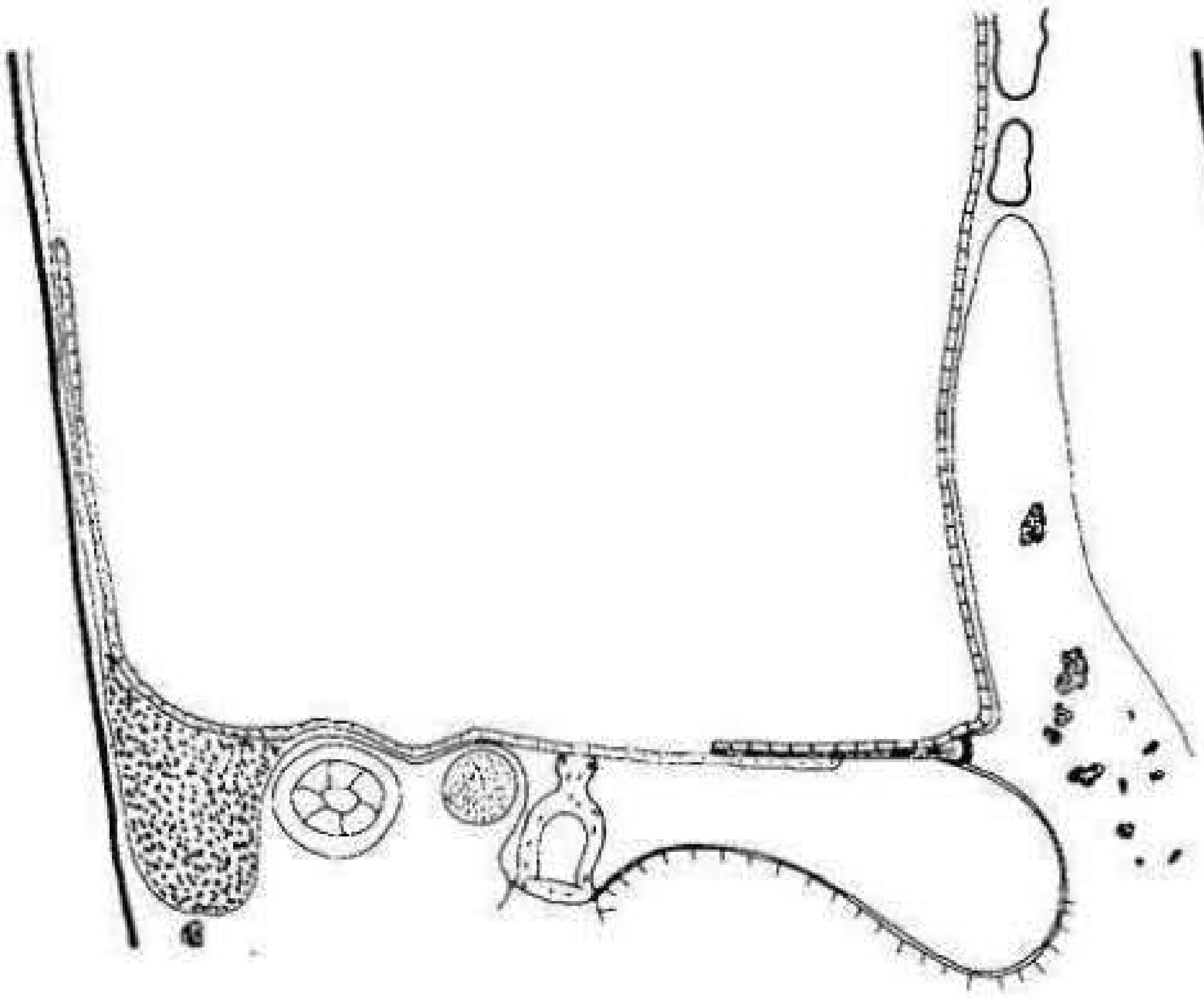


Fig. **687** **Partial obliteration with bone paté** in a situation with no ossicles, except the stapes. A myringostapediopexy is created, placing the fascia as an underlay graft onto the head of the stapes, the facial nerve, and the lateral semicircular canal. The fascia covers the bone paté placed in the perilabyrinthine groove

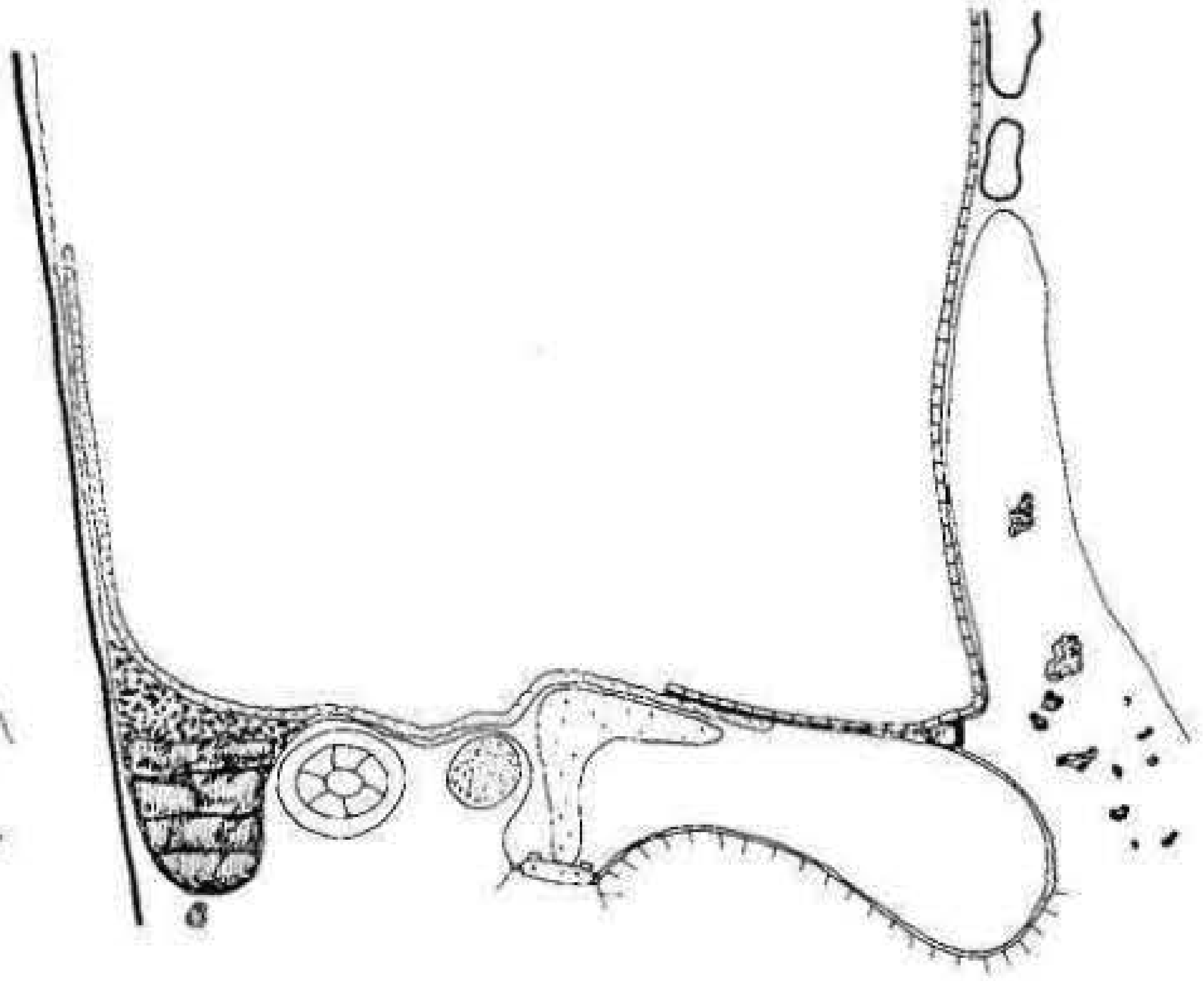
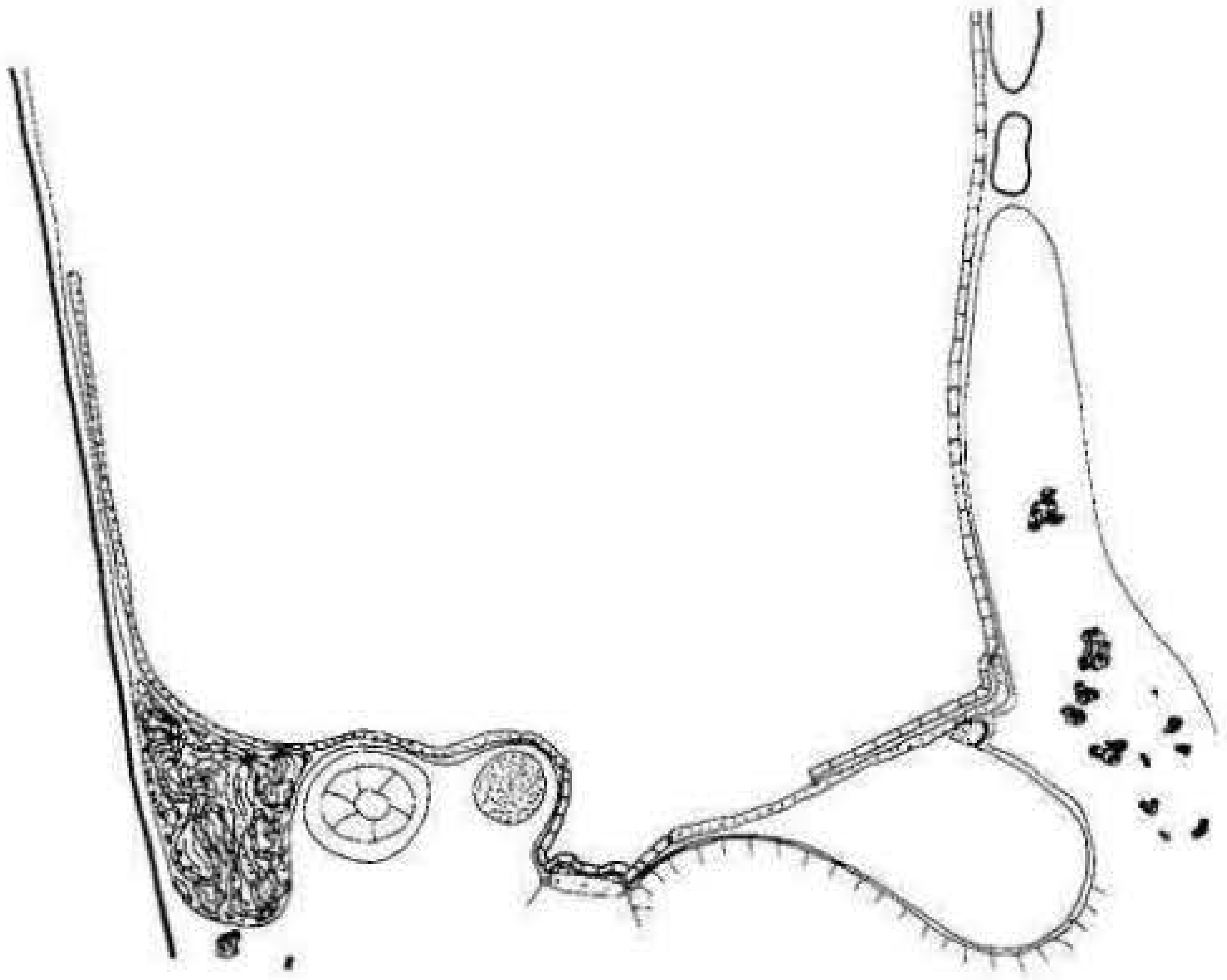


Fig. **688** **Partial obliteration of the medial attic with small bone chips and bone paté** in a situation with no ossicles and no stapedial arch. An L-shaped piece of cortical bone columella is placed on the footplate, and a fascial graft covers the drum perforation and the attic. The attic groove is obliterated with small bone chips and bone paté

Fig. **689** **Partial obliteration of the medial attic with fibrous tissue** after an endaural canal wall–down mastoidectomy, with a deep groove between the tegmen tympani and the lateral semicircular canal. There are no ossicles, and a type IV tympanoplasty is performed with the fascia placed on the annulus and on the promontory, orotecting the hypotympanum and the round window niche. A small split-skin graft is placed on the footplate and the stapes niche. The attic wall is further covered with fascia



graft covers the medial wall of the cavity, the facial nerve eminence, and the lateral semicircular canal (Fig. **689**). A split-skin graft (Tirsch graft) is placed in the oval window niche and on the footplate.

Various Methods of Myringoplasty, Ossiculoplasty, and Attic Ventilation

A wide variety of *myringoplasty methods* are used in the canal wall–down situation.

The fascia can be placed as an overlay or underlay graft, as described in Vol. 1, but it is usually placed as an underlay graft, chiefly because it is easier to place a large fascial graft along the cavity wall and over the facial ridge into the tympanic cavity. The preserved ear canal skin flaps promote epithelialization of the cavity (Figs. **672–688**). Moreover, in cases with a low tympanic cavity and thick mucosa, placing the fascia on the fibrous annulus as an *onlay* graft (Fig. **689**) may enlarge the tympanic cavity.

The wide variety of *ossiculoplasty methods* used in the canal wall–down situation result from the variability of ossicular pathology and the many ossiculoplasty methods available, as well as the many materials that can be used (described in Vol. I). Only examples using autogenous incus and cortical bone are shown in Figures **675–688,** mainly because these methods are the author's methods of choice in cases with mastoidectomy. Cortical bone is especially easy to access, but cartilage, hydroxyapatite, and other materials can also be used.

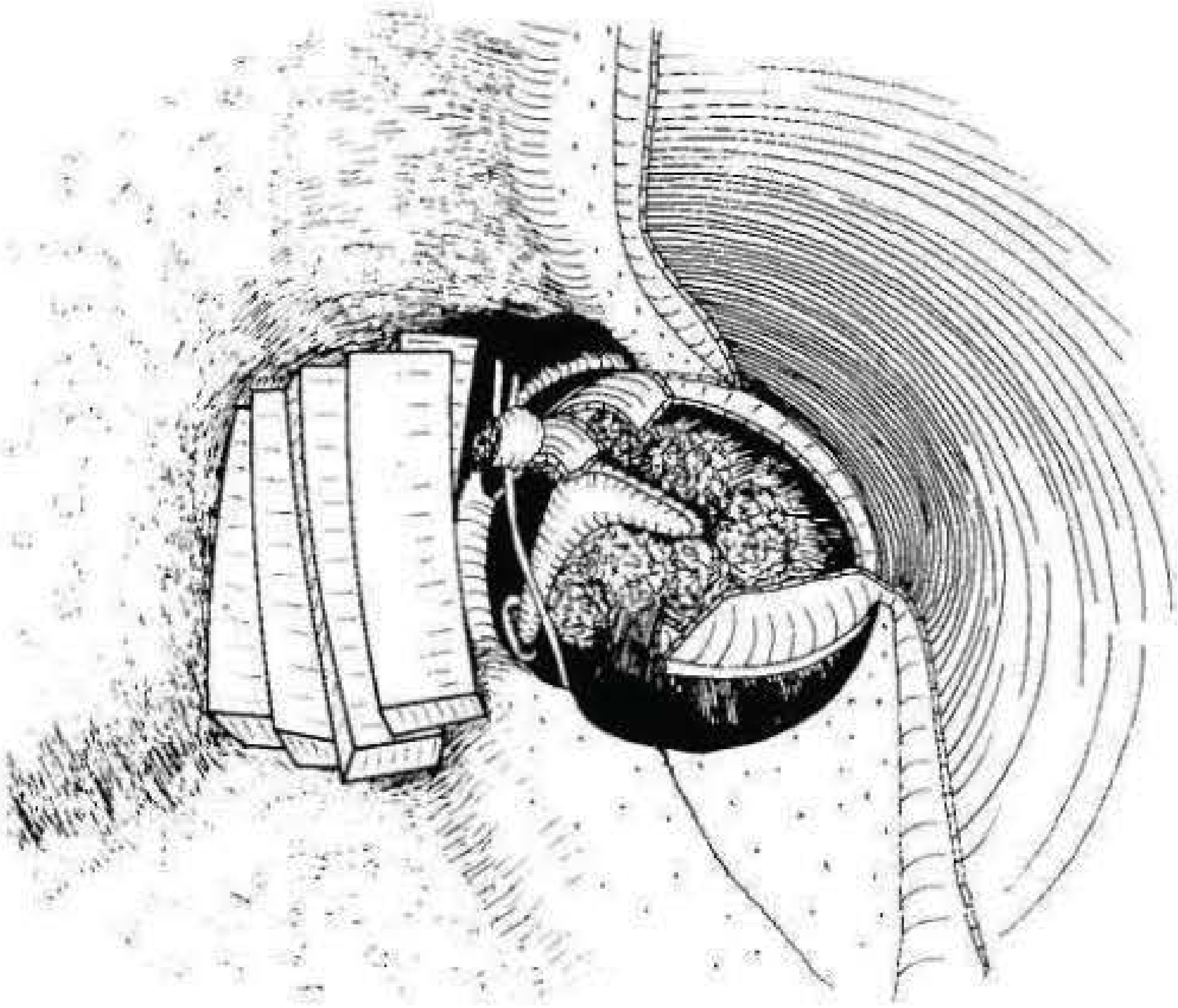


Fig. **690** **Obliteration of the attic in an endaural canal wall–down mastoidectomy with no ossicles except malleus handle.** An L-shaped piece of cortical bone columella is placea on the footplate, supported by Gelfoam. The attic is obliterated with several palisades of tragal cartilage placed in two rows, to enlarge the height of the attic

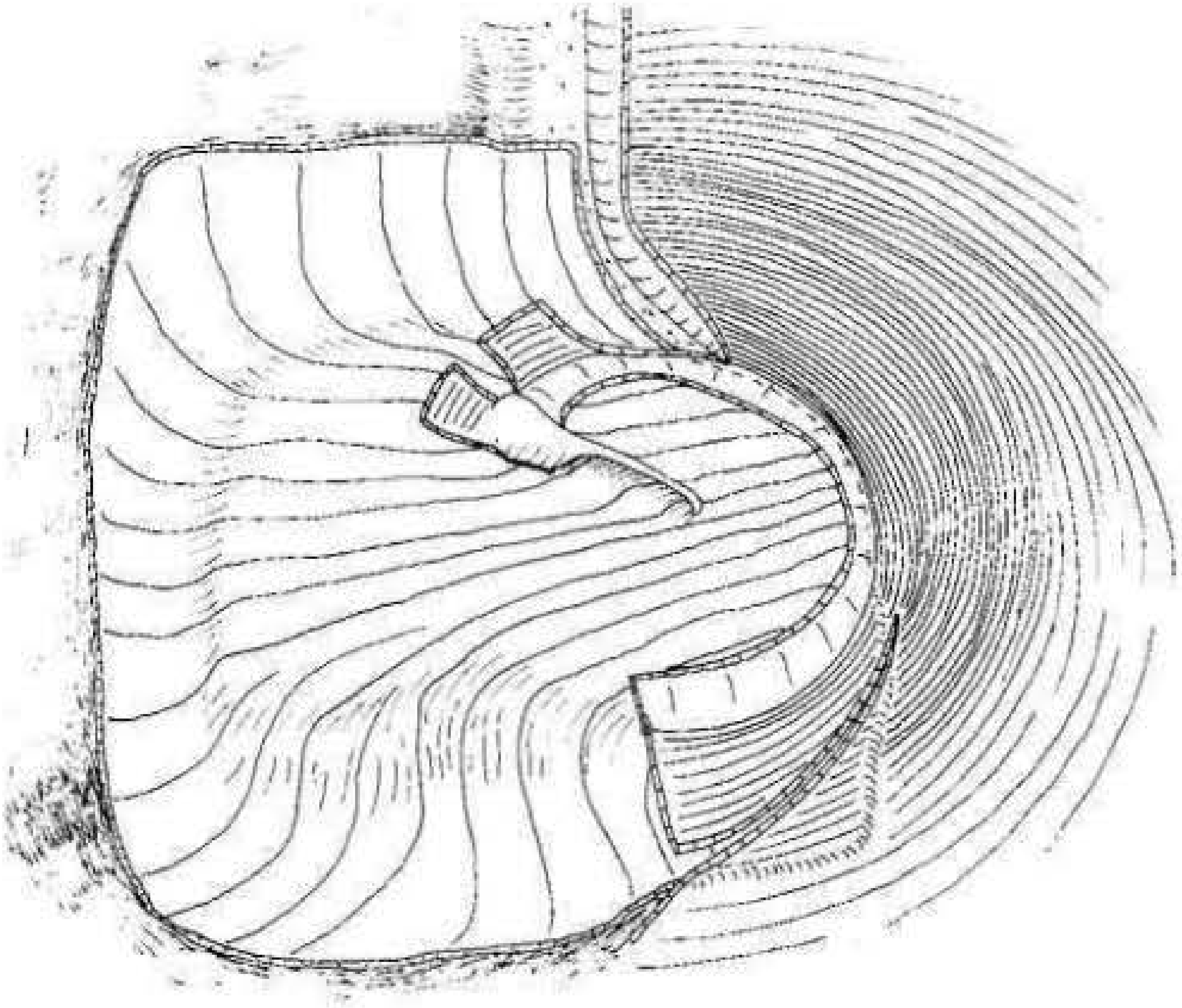


Fig. **691** The fascia covers the perforation, the columella, the tragal cartilage palisades and the medial cavity wall as an underlay graft

Open or closed attic. In the situations illustrated in Figures **680–682** and **685–689,** the fascia is placed on the medial wall of the cavity and the tegmen tympani as well as over the facial ridge, creating an open cavity in the attic and the aditus regions, with no ventilation. In cases with an intact ossicular chain (Figs. **671–673**), the attic forms a closed cavity, and is intended to be ventilated. In cases with the malleus head present (Figs. **675–678**), only the anterior attic is ventilated, but the posterior attic and aditus are included in the open cavity. In cases with a missing malleus (Fig. **684**), the attic can still be ventilated. The possibilities for variable ventilation of the attic further contribute to the wide variability of methods that can be applied in canal wall–down cavity reconstructions.

Partial or Total Obliteration of the Attic

The attic can be partially or totally obliterated using various materials. In the deeper part of the attic, after exenteration of the perilabyrinthine cells or removal of a cholesteatoma involving these cells, a deep groove between the tegmen tympani and the lateral semicircular canal may be result. The groove can be obliterated separately, either with small pieces of conchal or tragal cartilage along with attached perichondrium (Fig. **686**), bone paté (Fig. **687**), small bone chips supported with bone paté (Fig. **688**) or fibrous tissue (Fig. **689**).

The attic can also be totally obliterated, and the purpose of such an obliteration is usually to elevate the medial attic wall to the level of the bridge to act as a support for the fascia in order to achieve a deeper tympanic cavity and a larger area of vibrating membrane (in contrast to placing the fascia on the facial prominence). Strips of cartilage can be used to elevate the attic wall (Fig. **690**). The first palisade is placed on the lateral semicircular canal, and the following palisades fill the space in the attic. After ossiculoplasty, the fascia, as an underlay graft, covers the palisades and the tegmen tympani (Figs. **691, 692**).

Pieces or plates of cortical bone are also used to elevate the medial attic wall. Other materials, such as bone paté and hydroxyapatite, are also currently, popular. Previously, several strips of lyophilized dura have been used.

The methods of attic obliteration described can be used as the only obliteration, leaving the remaining cavity open. But they can also be used in connection with obliteration of the cavity and reconstruction of the ear canal. These methods will be described in separate chapters.

Preservation of an Intact Bridge in Endaural Mastoid Surgery

Arguments for preserving the bridge include maintaining the proper height of the tympanic cavity whilst avoiding risk of leaving residual cholesteatoma under the thin bridge, as well as possibly ventilating the attic in canal wall–down mastoidectomy. In endaural surgery, starting with inside-out drilling of the ear canal, initial preservation of the bridge appears to be a logical as well as a "conservative" start to the conservative radical operation. In fact, the preservation of an intact bridge in canal wall–down mastoidectomy was popular in the 1940s and 1950s, but since introduction of intact canal wall mastoidectomy techniques, these methods and their modifications (Chapter 6) have lost support among ear surgeons. Great efforts were made to preserve an entirely intact ear canal wall, at one extreme — but if this was not possible, efforts were made to take it down completely, at the other extreme. The possibility of preserving the entire bridge, or a part of it, has not been sufficiently considered in cholesteatoma surgery in the author's opinion, and there is no evidence to demonstrate long-term advantages or disadvantages of the intact bridge techniques published so far. Only Paparella (Paparella and Young 1983, 1984, Goycoolea et al. 1989) has consistently applied intact bridge mastoidectomy techniques and developed some new and interesting methods.

Inside-Out Mastoidectomy with Preservation of the Bridge

Inside-out mastoidectomy starts with a posterior tympanotomy and atticotomy, keeping the bridge intact.

Posterior tympanotomy. In posterior tympanotomy, the drum remnant and tympanomeatal flaps are elevated, and the pathology of the posterior tympanum is removed (Vol. 1, Figs. **173–184**). If the pathology extends into the sinus tympani, e. g., in sinus cholesteatoma, otosclerosis drilling is performed to visualize the sinus tympani transmeatally. Further otosclerosis drilling may be necessary to expose the pyramidal eminence and the genu of the facial nerve, allowing good visualization of all tympanic sinuses. The posterior part of the bridge is thus displaced further superiorly. This method differs from the outside–in mastoidectomy method with preservation of the bridge, as illustrated in Chapter 11, Figs. **611–612**, because in the retroauricular approach the bridge is preserved in its original position, and a posterior atticotympanotomy is performed through the facial recess in order to clear the pathology from the sinuses (Fig. **613**). Even in cases with a partially preserved bridge (Figs. **592–596**), the posterior atticotympanotomy is performed similarily in retroauricular mastoidectomy. In endaural mastoidectomy, the posterior atticotympanotomy is not performed, and the preserved bridge is displaced to the extent required by the pathology.

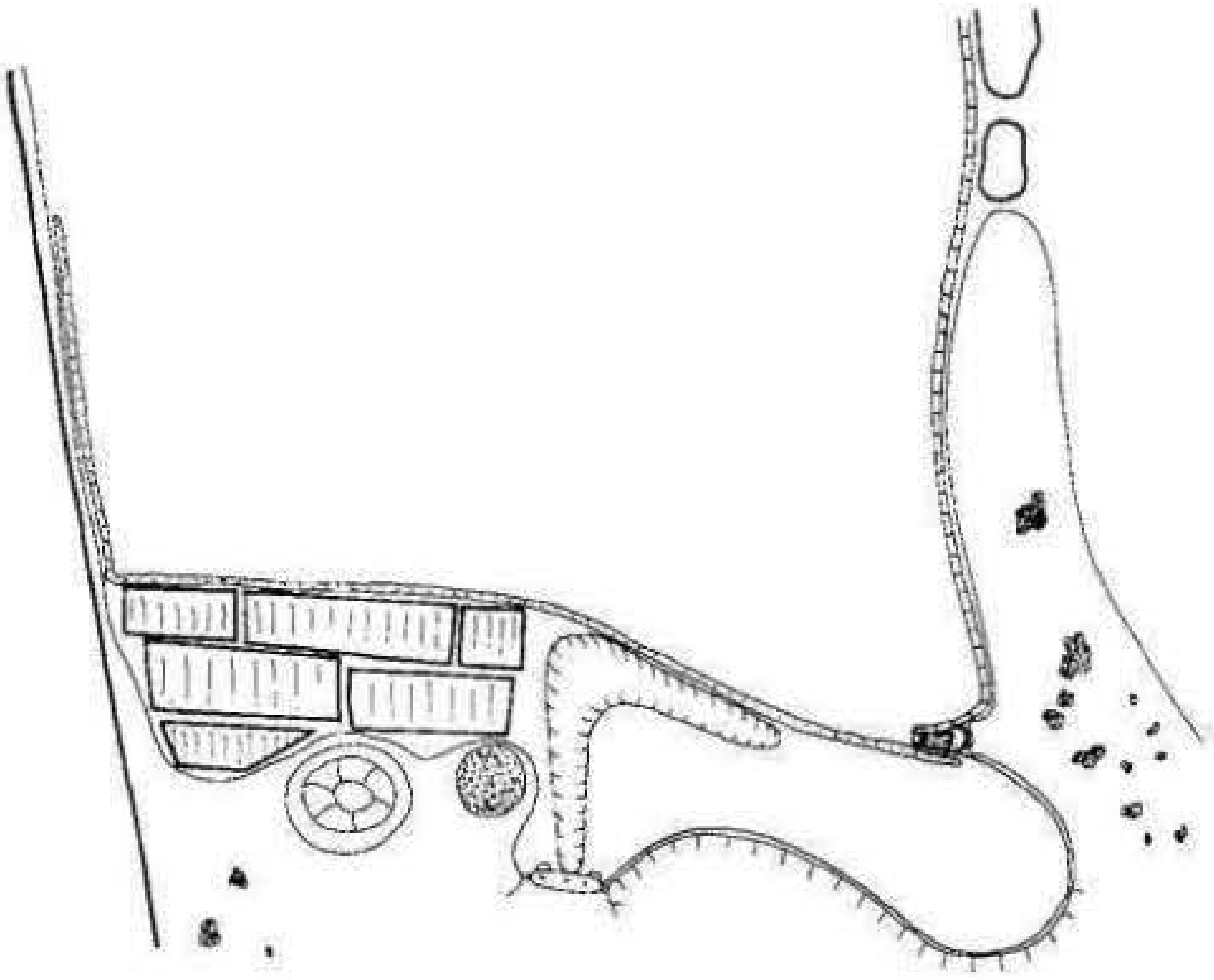


Fig. **692** Side view of the obliteration of the attic, illustrating the support for the fascia provided by the cartilage palisades

Atticotomy. By enlarging the ear canal lateral to the bridge, the lateral attic wall is removed (Fig. **693**), carefully preserving the bridge as in the transmeatal atticotomy method described in Chapter 7 (Figs. **391–407**). The attic is exposed and the pathology is removed. If the pathology can be safely removed, a limited atticotomy (as illustrated in Figs. **1** and **7**) is sufficient, and the attic defect is closed with cartilage or bone and the operation completed with a tympanoplasty (Fig. **694**).

Atticoantrotomy. With further drilling in both posterior and inferior directions, the antrum is opened (Fig. **695**) and an atticoantrotomy is performed. If the pathology can be safely removed, the posterior canal wall is then reconstructed with cartilage or bone, and the antrum and attic are reventilated (Fig. **696**).

With further drilling toward the mastoid tip, and polishing of the mastoid tegmen, the atticoantrotomy is gradually enlarged, resulting in a canal wall–down mastoidectomy with preservation of the bony bridge. The transition from atticoantrotomy to mastoidectomy is gradual, and it is difficult to say precisely when a large atticoantrotomy should be called a canal wall–down mastoidectomy.

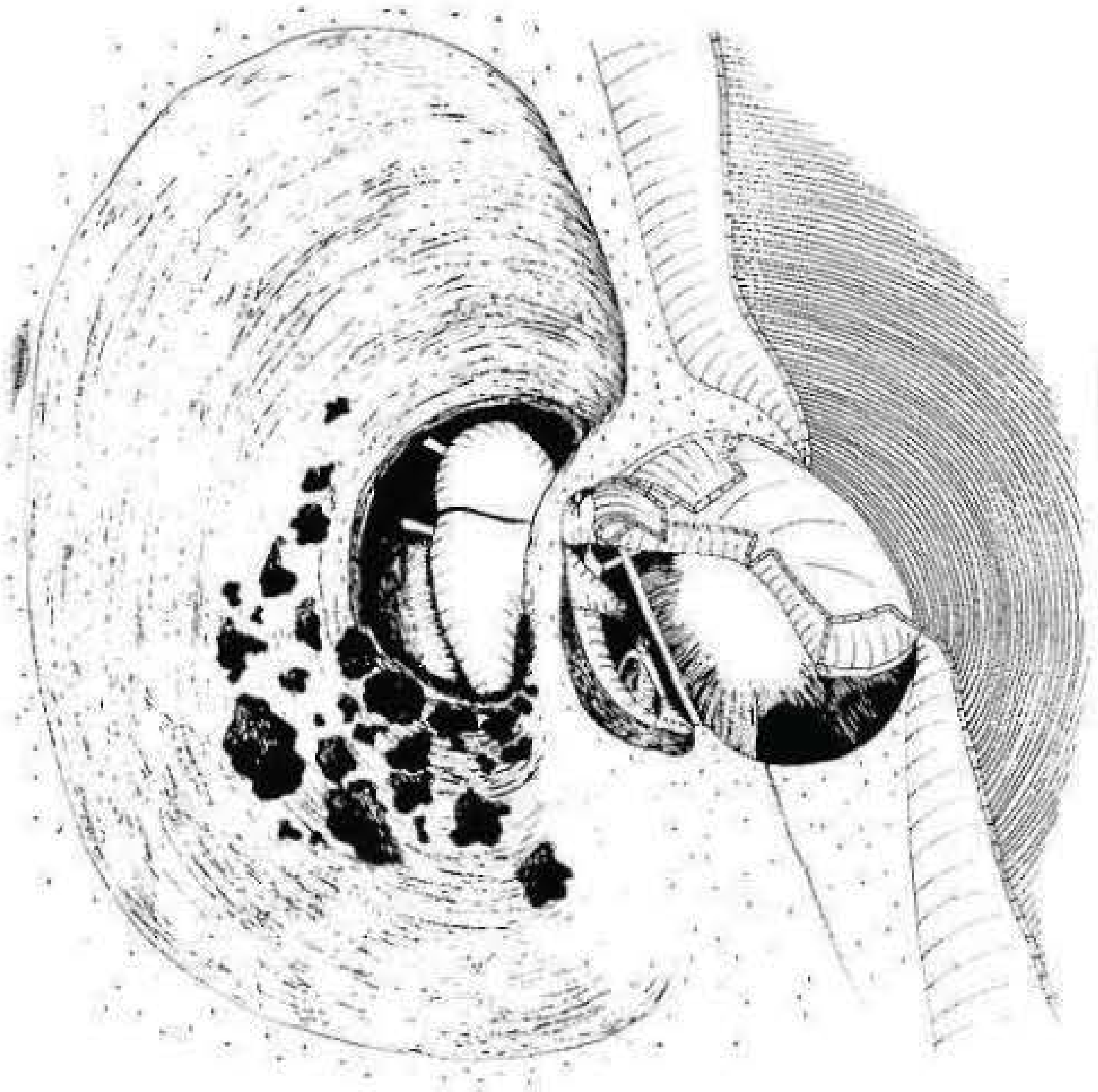


Fig. **693** **Start of the endaural canal wall–down mastoidectomy with atticotomy and preservation of the bridge.** After an endaural approach with elevation of the epithelial flaps and a posterior tympanotomy, the ear canal is widened, and otosclerosis drilling and an atticotomy are performed, preserving the bony bridge intact. Some air cells are visible toward the antrum

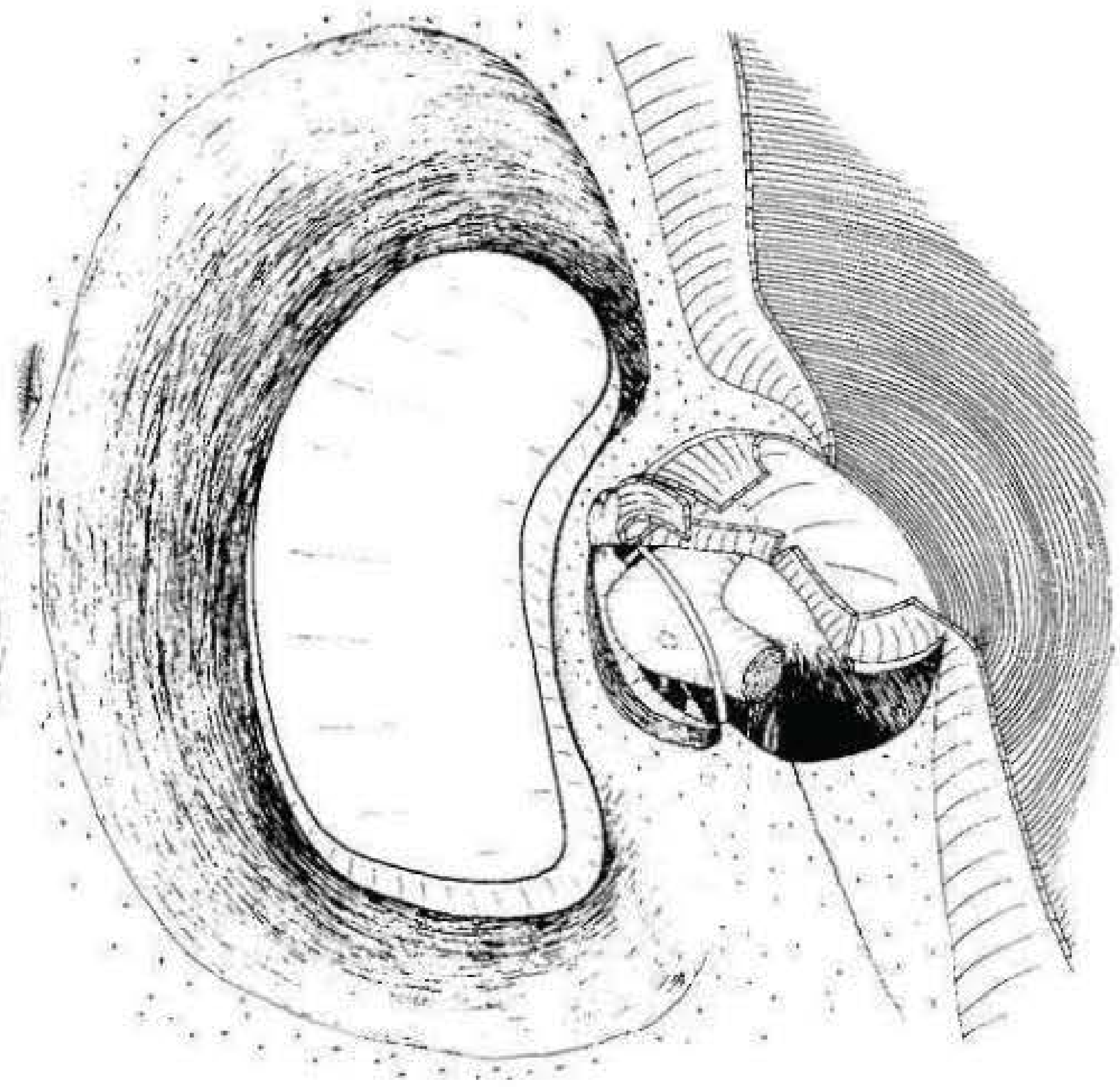


Fig. **694** **Covering the atticotomy with a cartilage plate.** An incus is interposed between the head and the stapes and malleus handle. The chorda tympani is supporting the incus. The drum perforation and the cartilage plate will be covered with a fascia graft

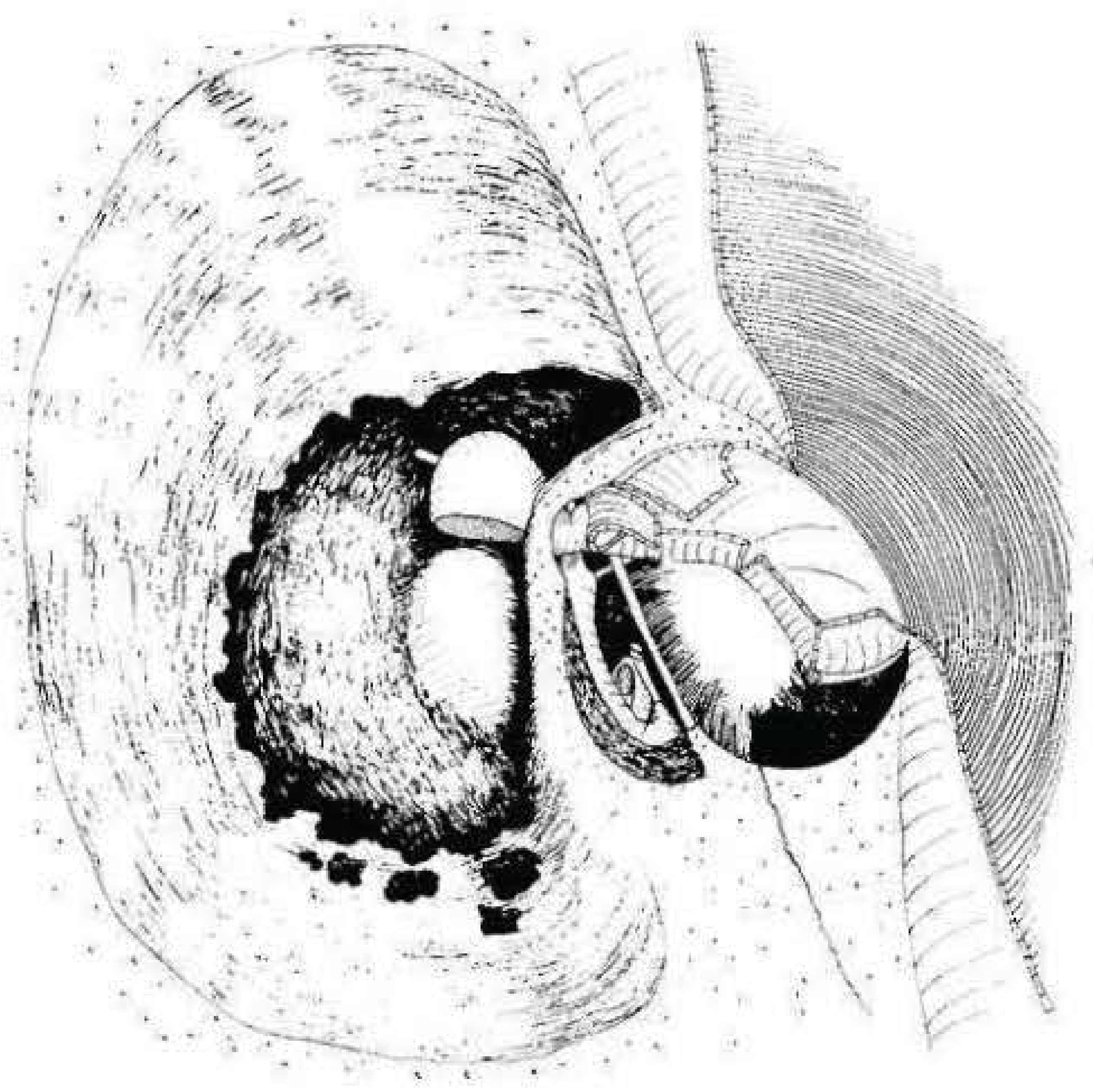


Fig. **695** **Atticontrotomy.** Further endaural removal of the bone, resulting in an atticontrotomy with preserved bridge. The incus is removed

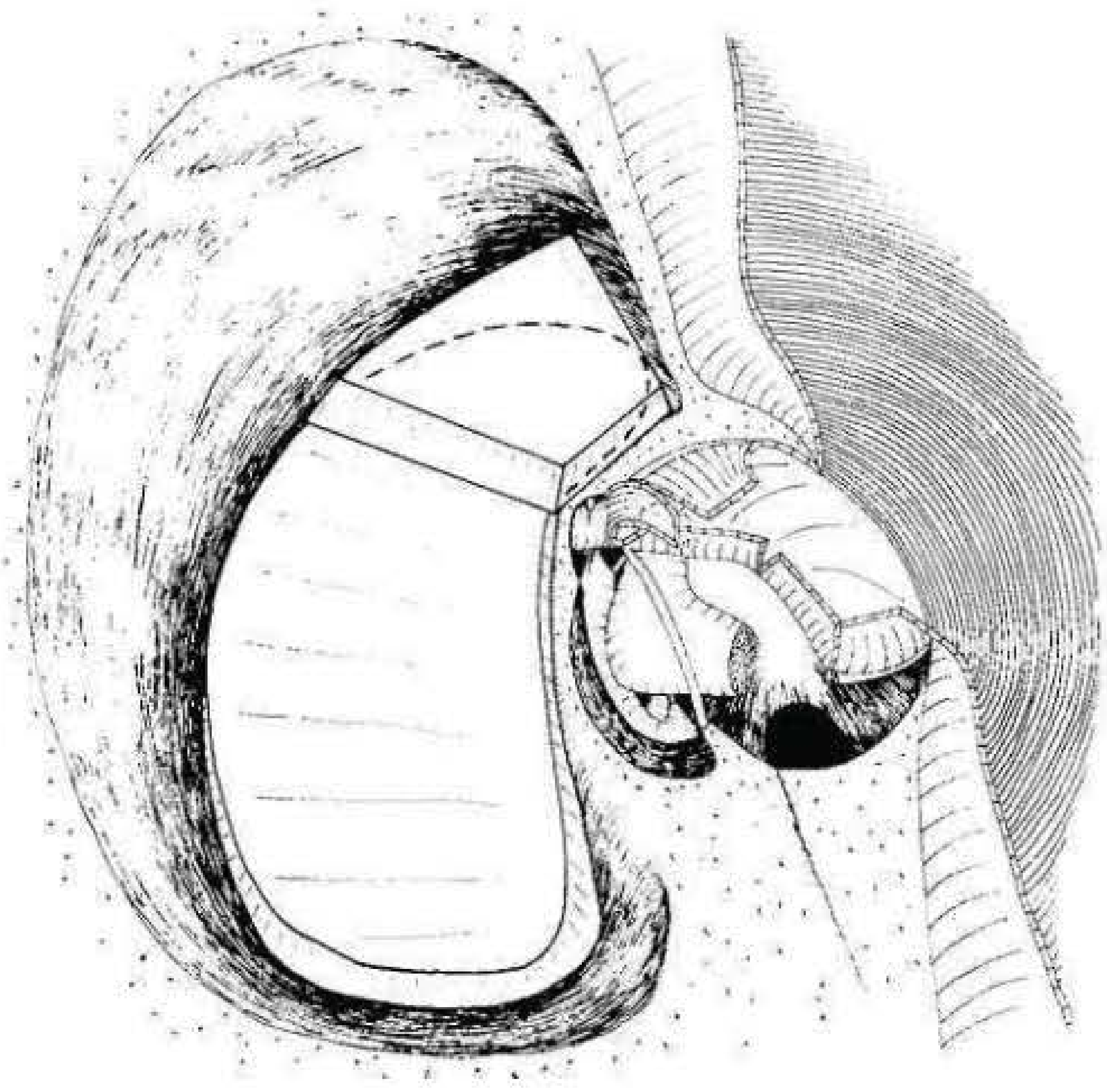


Fig. **696** **Covering the atticontrotomy with cartilage plates.** A larger cartilage plate is tailored to fit the defect and the preserved bony bridge, and another, smaller, plate covers the anterior part of the attic. The ossiculoplasty is performed with an interposed incus

In canal wall–down mastoidectomy, the bridge can be preserved in its original position (Fig. **48**); it can be displaced slightly superiorly (Fig. **49**); or it can be considerably displaced superolaterally (Fig. **50**). Partial or complete preservation of an intact bridge provides for a wide variety of reconstruction methods in canal wall–down mastoidectomy.

Retrograde Endaural Mastoidectomy on Demand

Mastoid surgery "on demand" describes procedures limited strictly to the extent of the pathology, with limited bone work and with immediate reconstruction of the removed ear canal wall (Olaizola 1985). As described in Chapter 12, with a retroauricular approach, in some situations a retrograde transcanal mastoidectomy with removal of the bridge is appropriate, e. g., in cases with an attic cholesteatoma and very extensive spontaneous resorption of the lateral attic wall (Figs. **640–644**). Following the extension of the attic cholesteatoma toward the mastoid process, the mastoidectomy is limited strictly to the size of the cholesteatoma, resulting in a small, open cavity. Of course, this method can also be used in an endaural approach.

In other situations, such as sinus or tensa retraction cholesteatoma, the cholesteatoma is often limited to the attic or aditus ad antrum. Retrograde mastoidectomy with preservation of the bridge can be applied, following the same principles as in mastoidectomy with removal of the bridge (Figs. **645** to **653**).

Typical types of "on demand" mastoid surgery are endaural retrograde mastoidectomy, starting with posterior tympanotomy and atticotomy with preservation of the bridge (Fig. **693**) and continuing to atticoantrotomy (Fig. **695**), and a small canal wall–down mastoidectomy (Fig. **697**). After each of these situations, the further surgery can be stopped and the ear canal completely reconstructed (Figs. **694, 696, 698**).

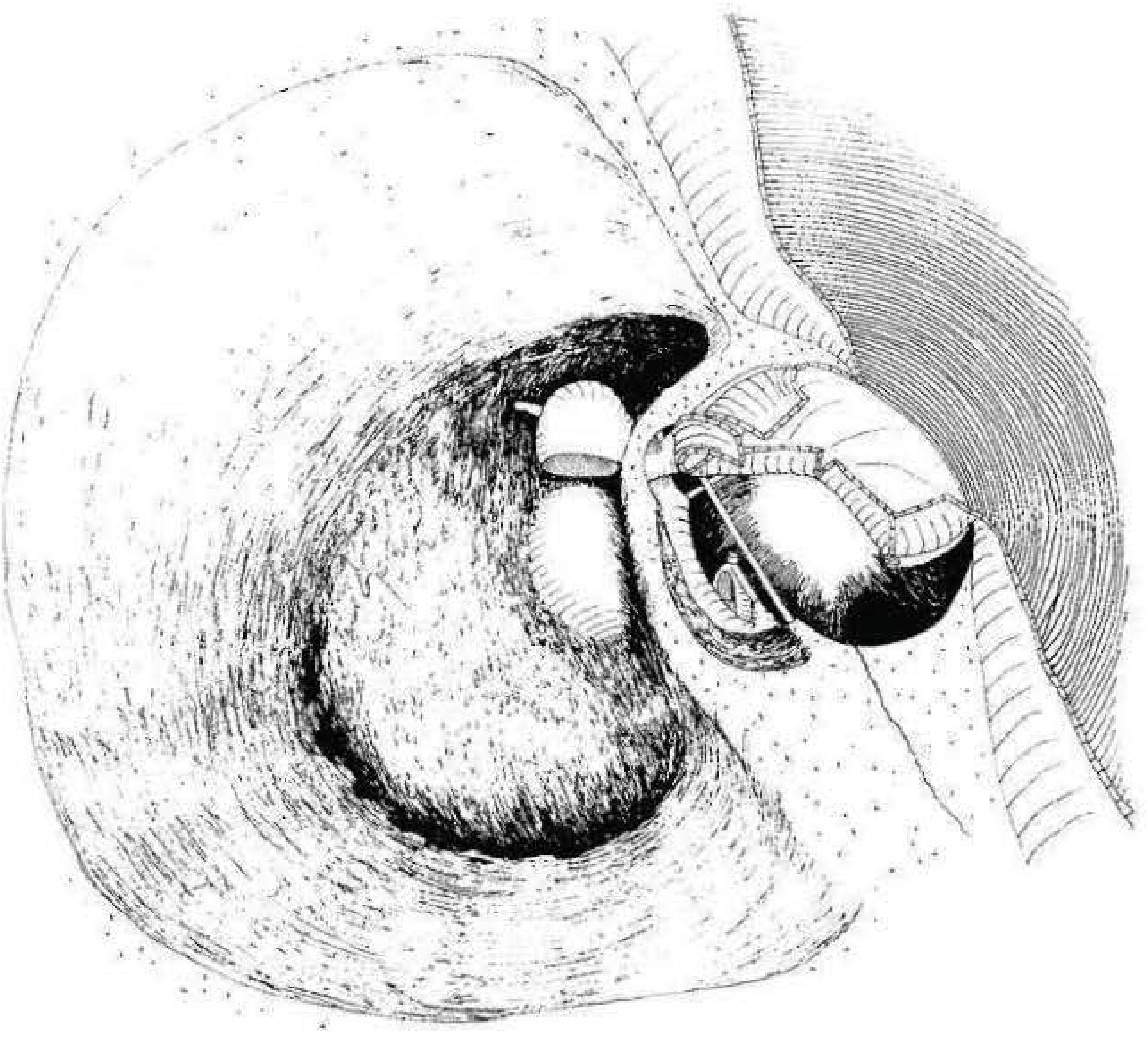


Fig. **697** The atticoantrotomy is further enlarged to a canal wall–down mastoidectomy. The middle fossa dura is smoothed, the sinodural angle is cleaned, and the mastoid cells are removed from the inferior part of the cavity

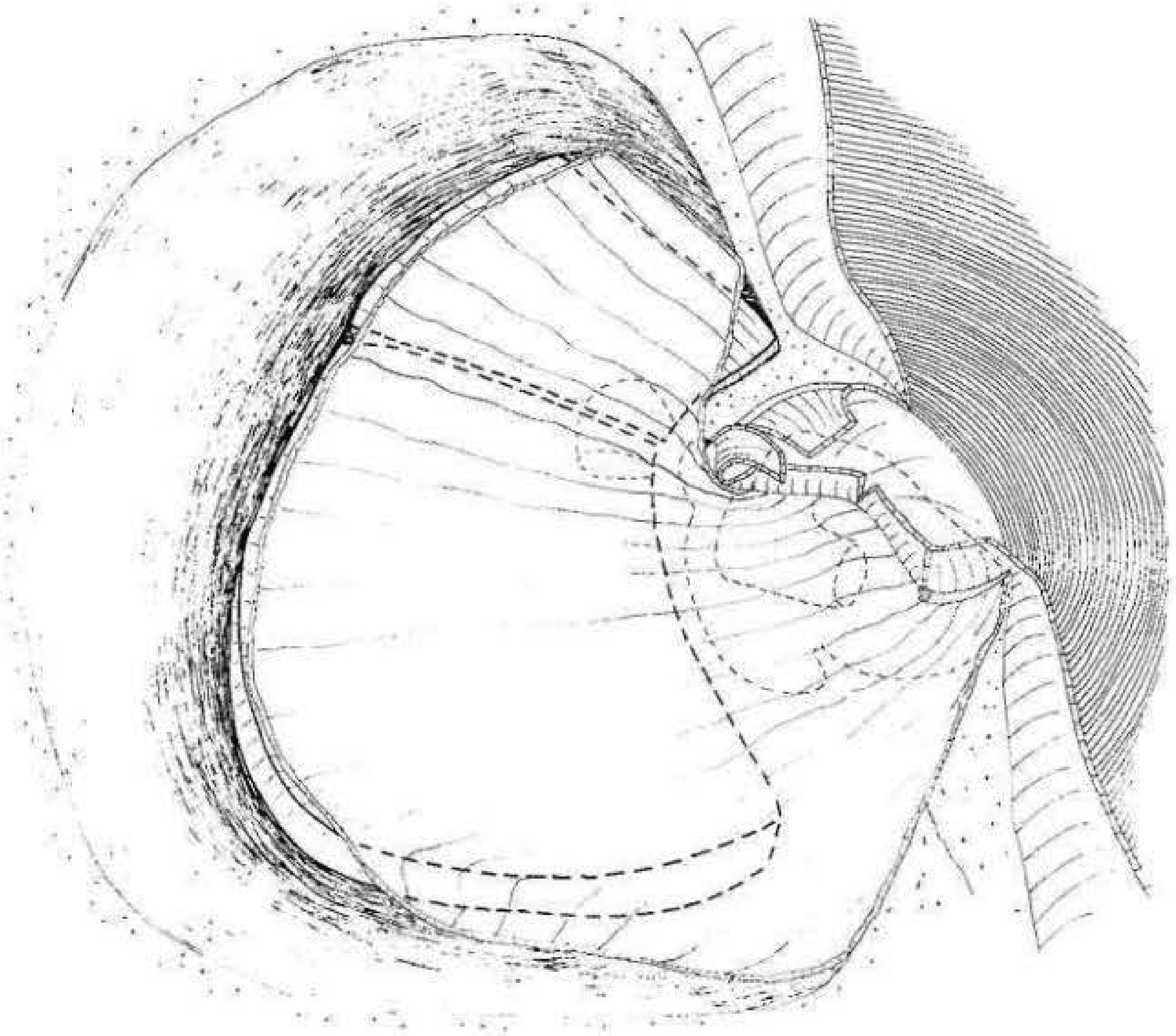


Fig. **698** **Covering the atticoantrotomy opening** with large cartilage plates in order to promote ventilation of the antrum. A large plate is placed posteriorly adapted to the preserved bony bridge, and a smaller one covers the anterior attic. The fascia is placed as an underlay graft, it covers the cartilage plates

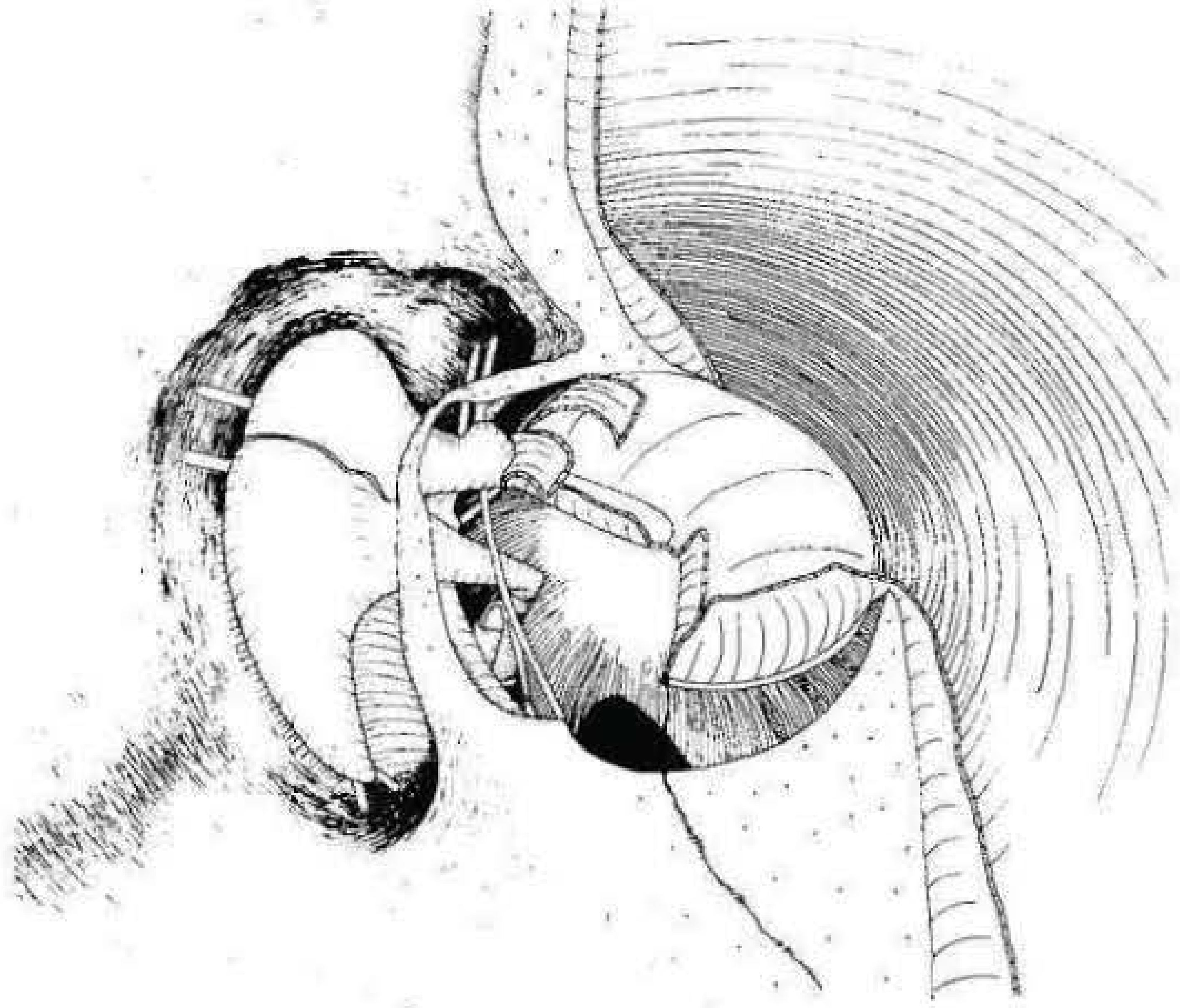


Fig. **699** An endaural canal wall–down mastoidectomy with a preserved bridge in a case with an intact ossicular chain

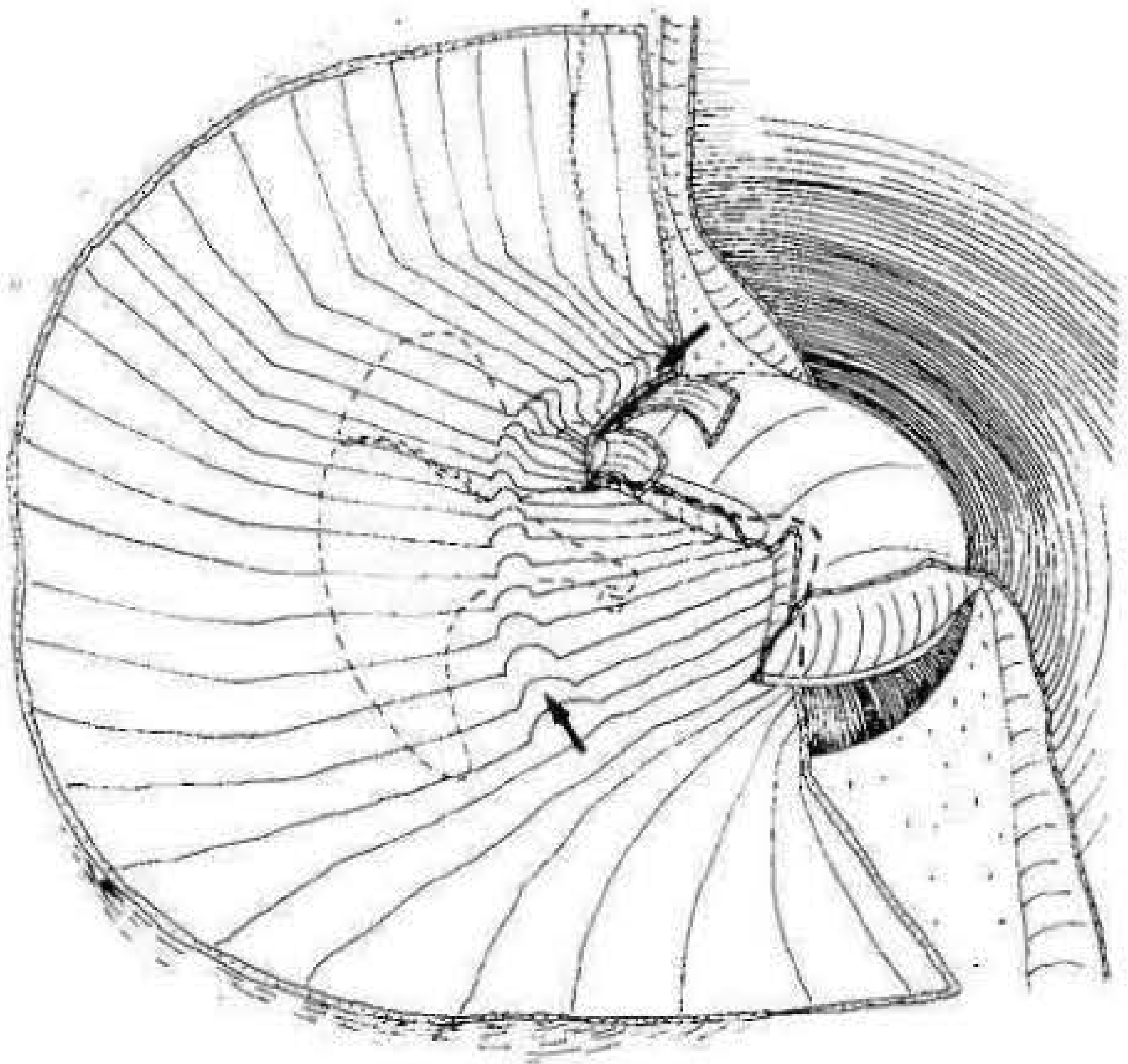


Fig. **700** The fascia covers the perforation as an underlay graft. It covers the preserved bridge (arrows) and is fixed to the tegmen tympani and antri. Inferiorly, the fascia covers the facial ridge and the cavity

Reconstruction of the Attic

Canal wall–down mastoidectomy with preservation of the bony bridge in its original position provides a good chance of ventilation of the attic, which is important for the hearing. In addition, an intact bridge facilitates obliteration of the cavity and reconstruction of the ear canal, as already demonstrated in Figures **696** and **698**.

In cases with an intact ossicular chain (Fig. **699**), a fascial graft is placed under the drum remnant, then over the bridge, the tegmen tympani and antri, and the facial ridge (Fig. **700**). After replacement of the ear canal skin flaps, the fascia is held in place with Gelfoam balls, and the entire attic is thus reventilated (Figs. **701, 702**).

In cases with a missing incus and minimally preserved bridge, all pathology can safely be removed

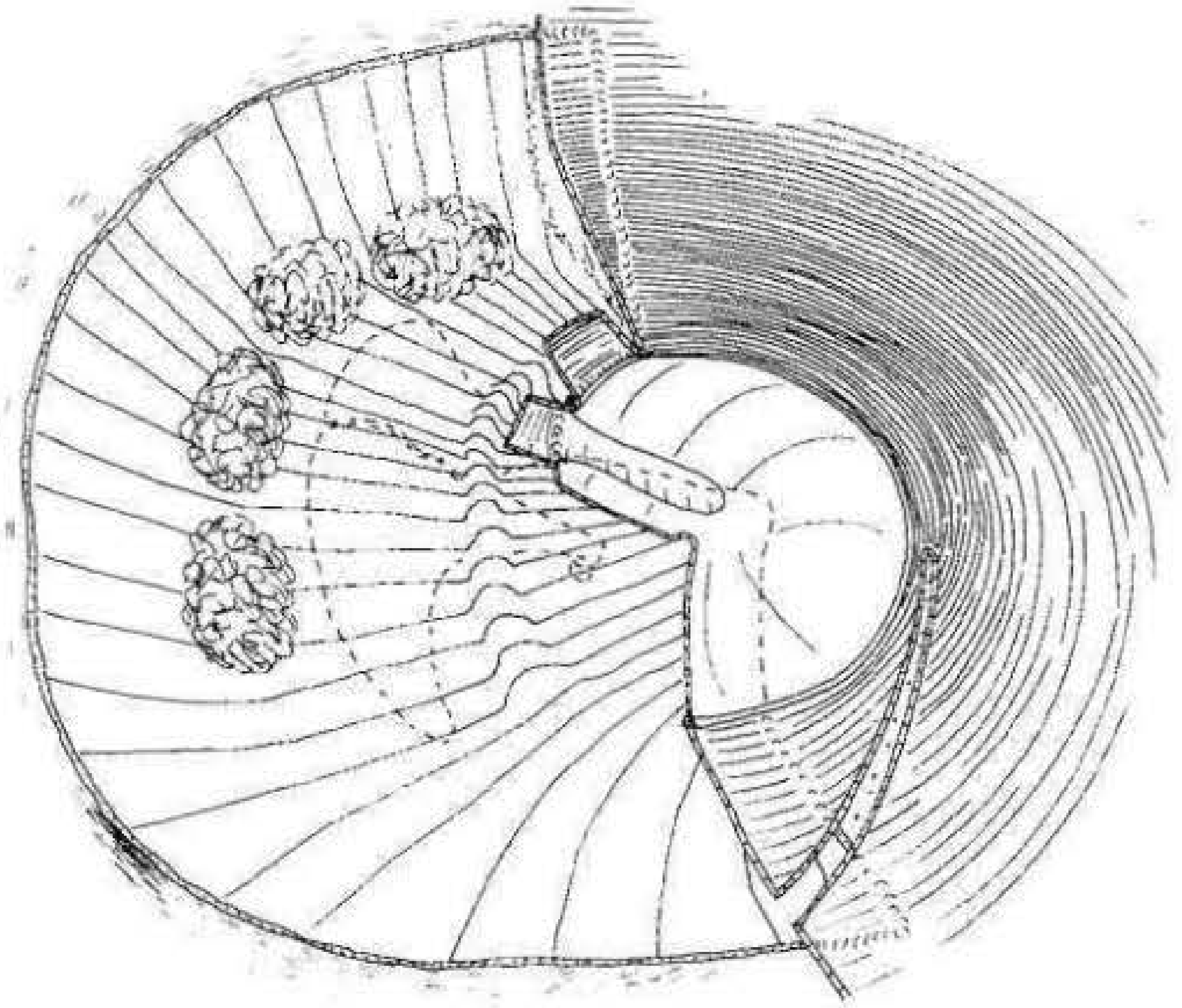


Fig. **701** The fascia is fixed with Gelfoam balls, and the skin flaps are replaced. The attic is intended to be ventilated

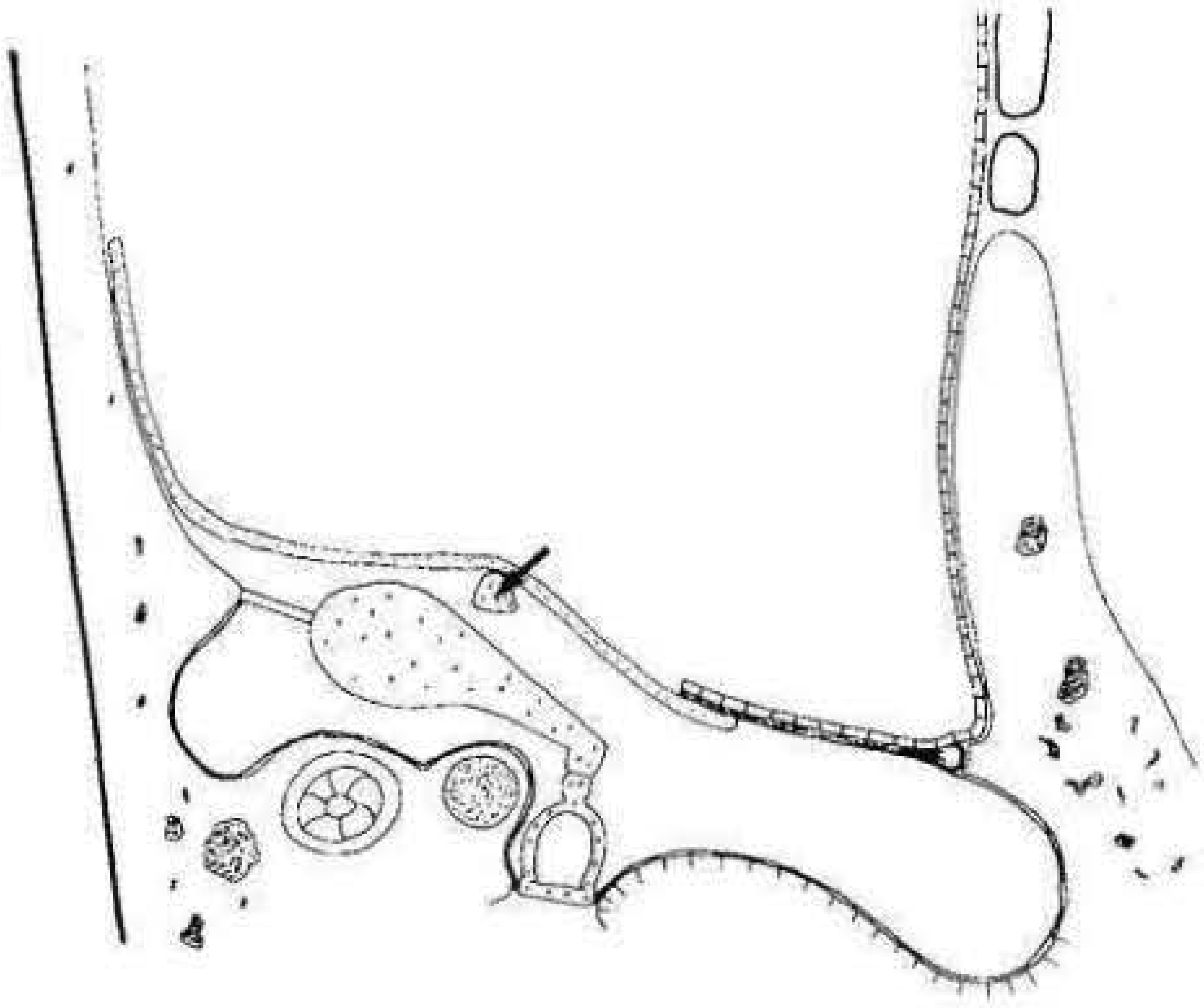


Fig. **702** Side view of the attic at the level of the intact incus. The fascia is placed on the preserved bridge (arrow) and the tegmen tympani, allowing ventilation of the lateral and medial attic

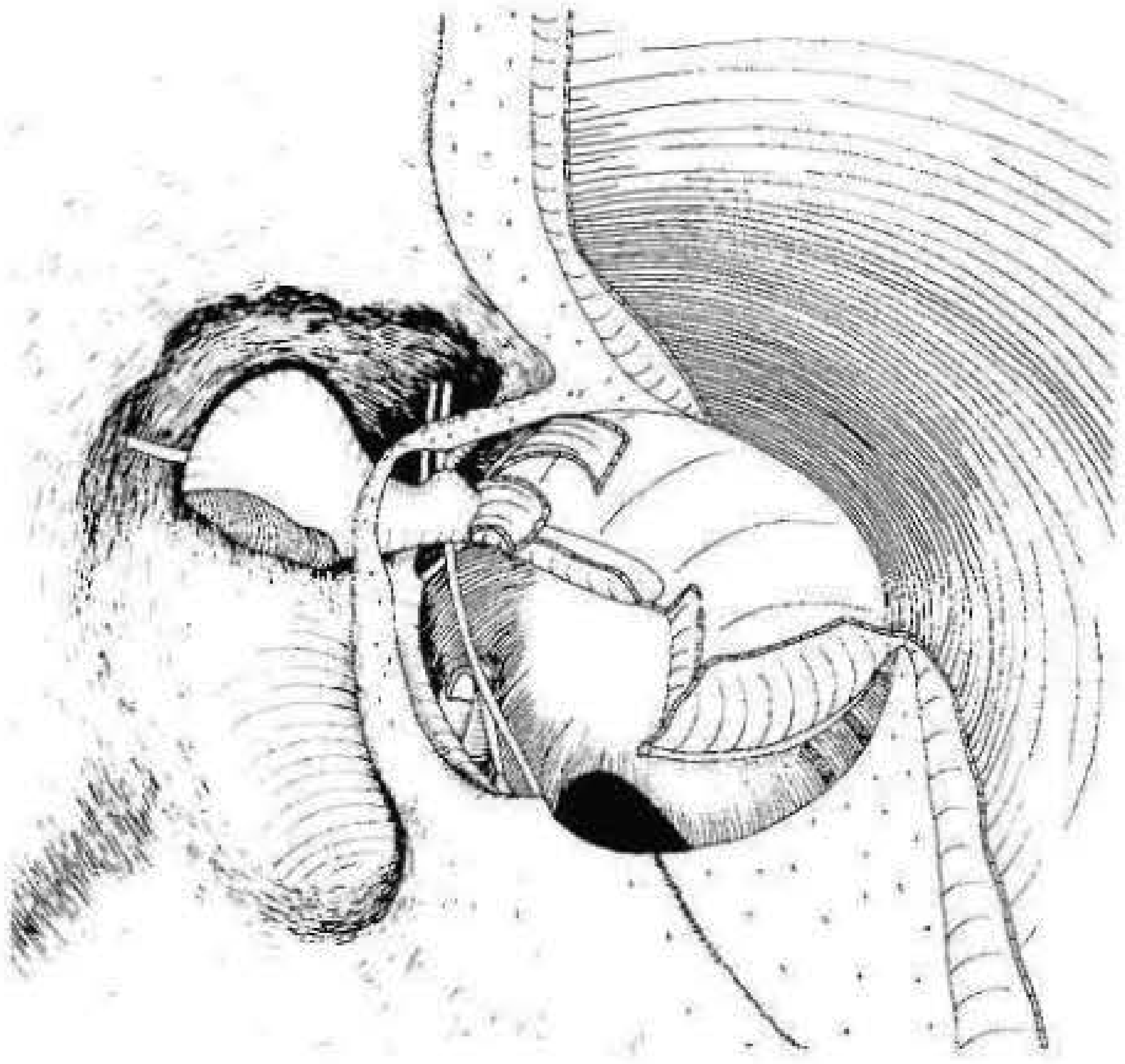


Fig. **703** **An endaural canal wall–down mastoidectomy with a preserved bridge** in a situation with a missing incus. The preserved bridge is thin, and all pathology has been safely removed. The stapes is present, and a good view of the anterior attic is provided

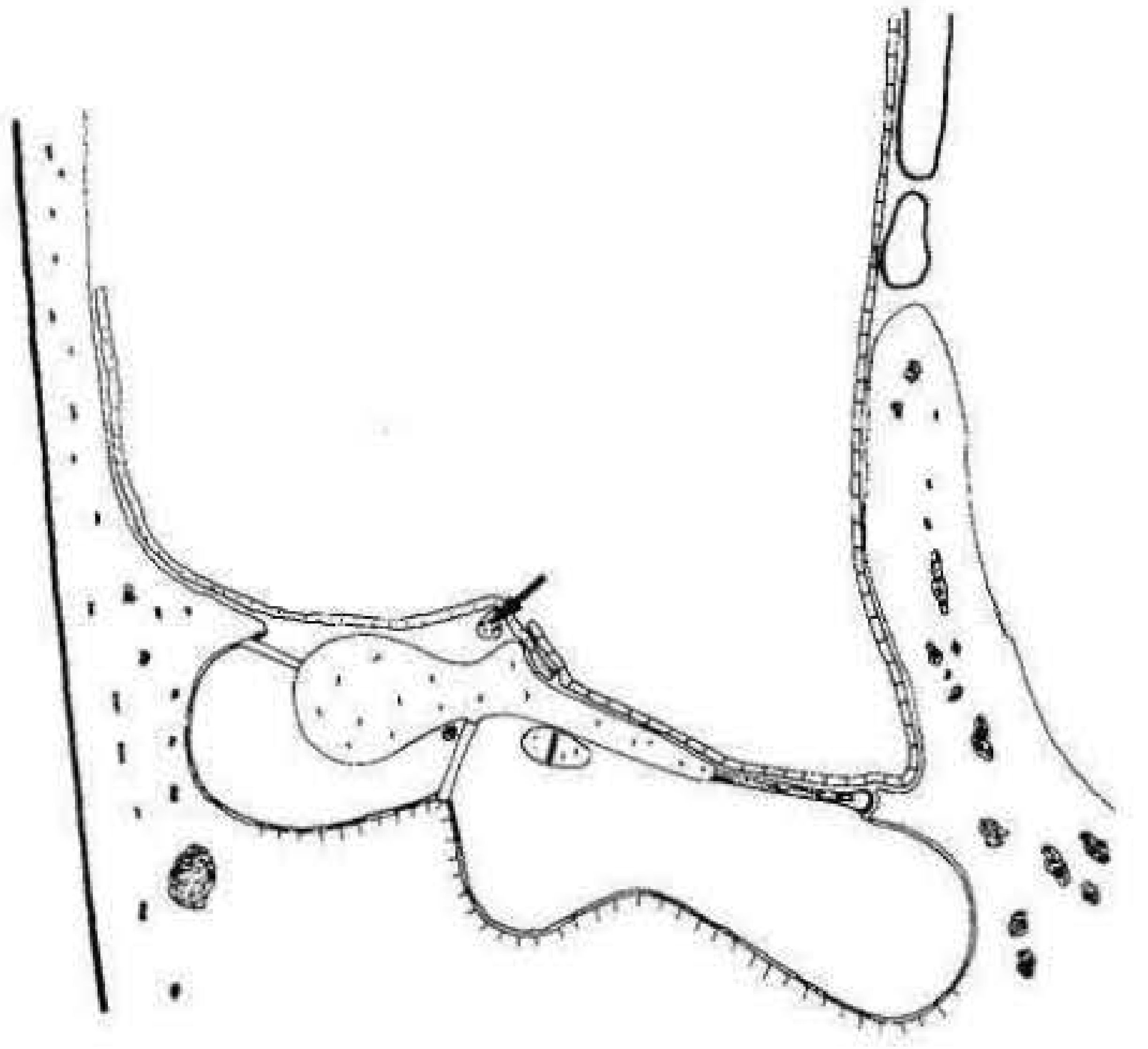


Fig. **704** The fascia covers the drum perforation and the preserved bridge (arrow), allowing ventilation of the attic. The short process of the incus (I) is visible under the malleus handle in the anterior attic (Fig. **703**). The malleus head is preserved intact, an ossiculoplasty is performed, and the drum perforation is then covered with a fascial graft placed over the preserved bridge and over the tegmen tympani, providing good ventilation of the attic (Fig. **704**).

In cases with a missing incus and malleus head, it is still sometimes worthwhile to preserve the bridge and ventilate the attic (Fig. **705**). A fascial graft covers the interposed incus, the bridge, the tegmen tympani and antri, and the medial wall of the cavity (Fig. **706**). After replacement of the epithelial flap, the attic is ventilated (Figs. **707, 708**). In cases with retraction and adhesion of the membrane to the medial wall of the attic, this type of retraction pocket will remain self-cleansing.

The function of the bridge, in the author's opinion, is particularly important in cases with a missing malleus head, because the bridge provides a support for the fascia, and movement of the malleus handle is not disturbed.

Sometimes the bridge can only be preserved in its anterior part, e. g., in sinus cholesteatoma (Fig. **709**) with no cholesteatoma involvement in the anterior attic. The anterior attic can be ventilated, because the bridge anteriorly supports the fascia (Fig. **710**) that is placed over the bridge and over the tegmen tympani. The posterior part of the attic forms an open cavity.

Often, the middle part of the bridge is not preserved, and this is regularly the case in attic cholesteatomas with extensive spontaneous erosion of the lateral wall (Fig. **711**). Reconstruction of the attic with a fascia graft provides stable conditions, especially in cases with an intact ossicular chain or preserved malleus head.

In cases with attic cholesteatoma, the entire anterior half of the bridge is removed (Fig. **712**), but the preserved posterior part provides good support for the drum. Anteriorly, the fascia is placed over the malleus head and tegmen tympani, providing pneumatization of the attic (Fig. **713**).

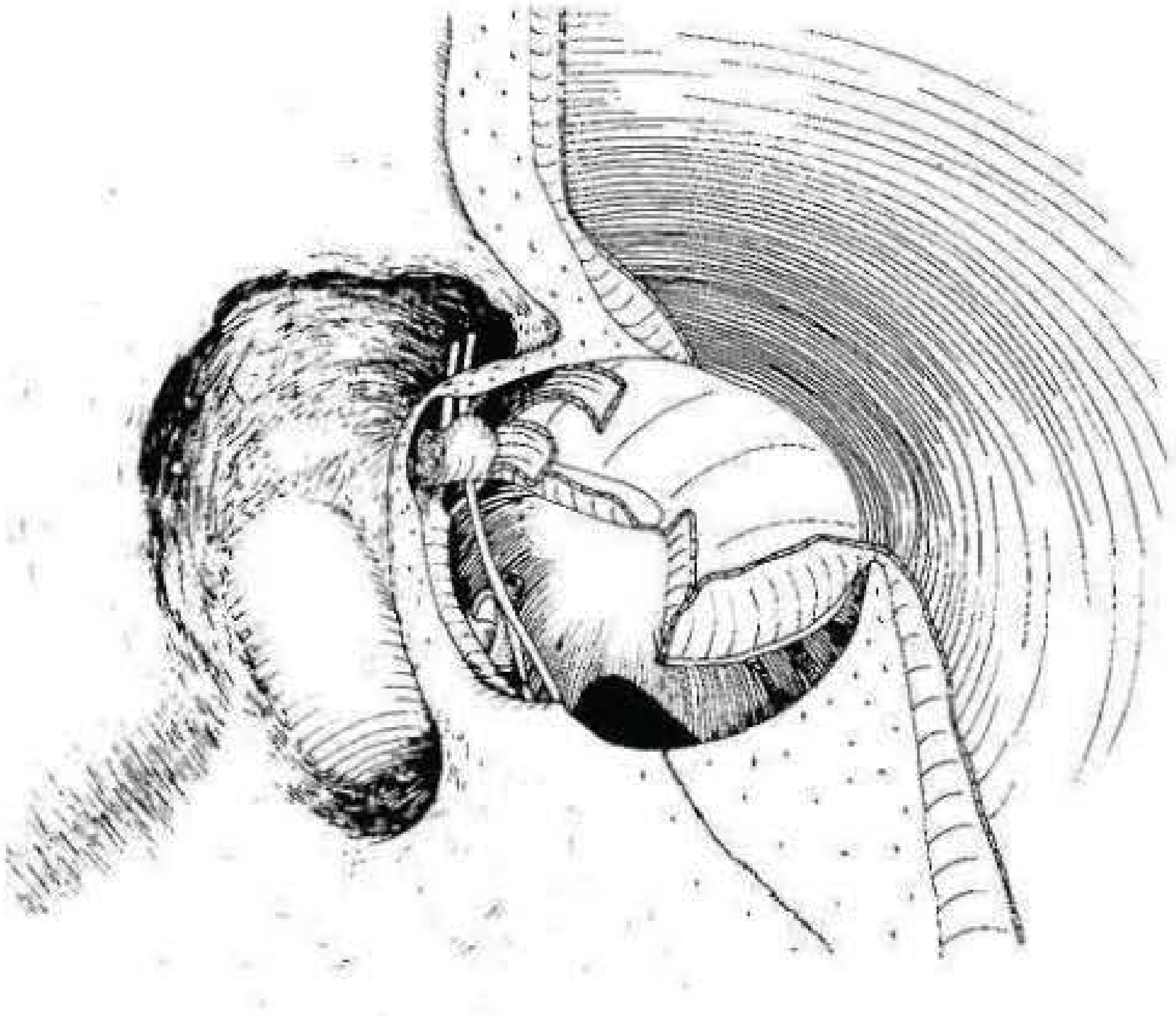


Fig. **705** **An endaural canal wall–down mastoidectomy situation with a preserved bridge in a case with a missing malleus head and incus**

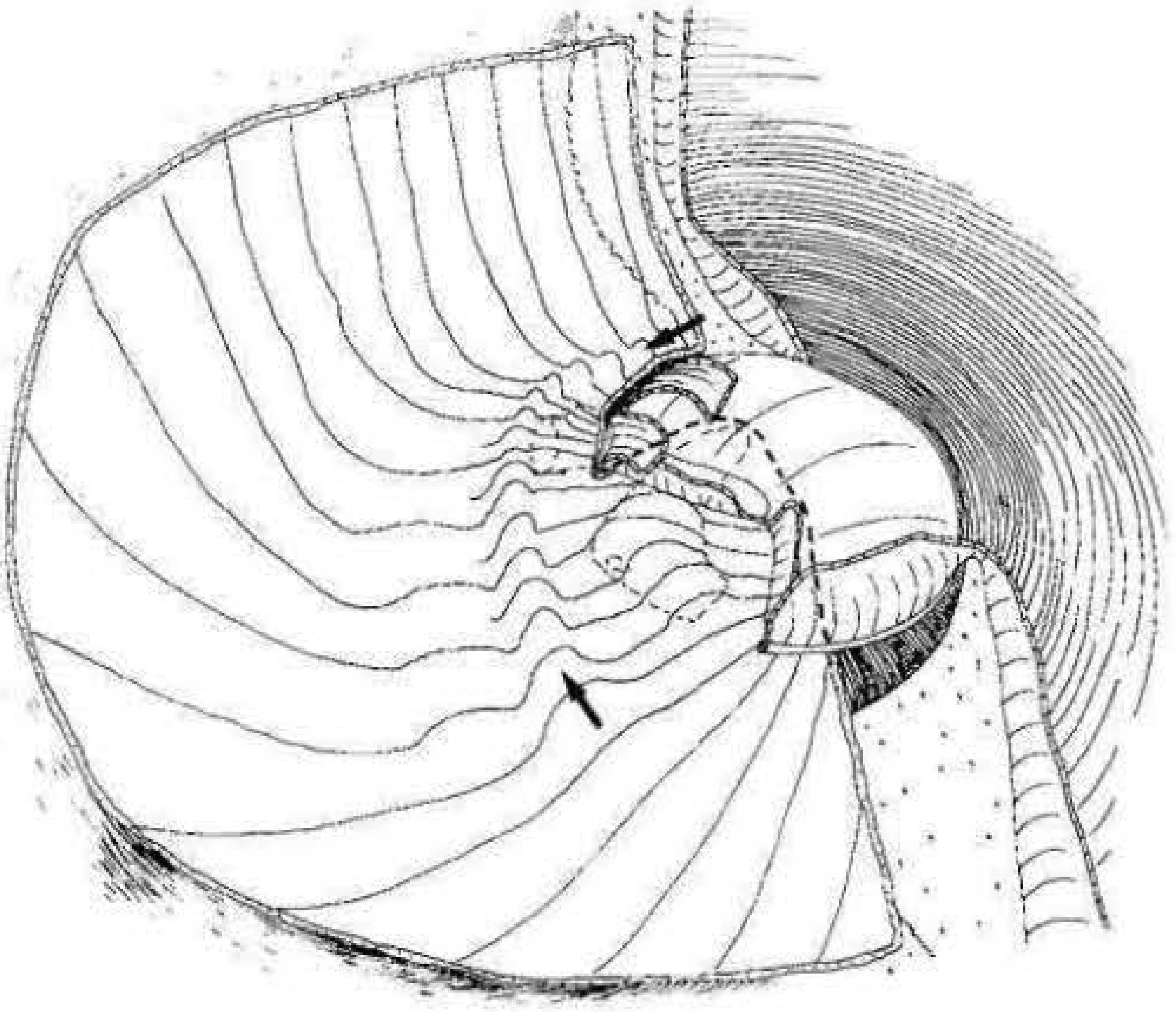


Fig. **706** The fascia is covering the drum perforation and the interposed incus as an underlay graft. It goes over the preserved bridge (arrows) and is attached to the tegmen tympani

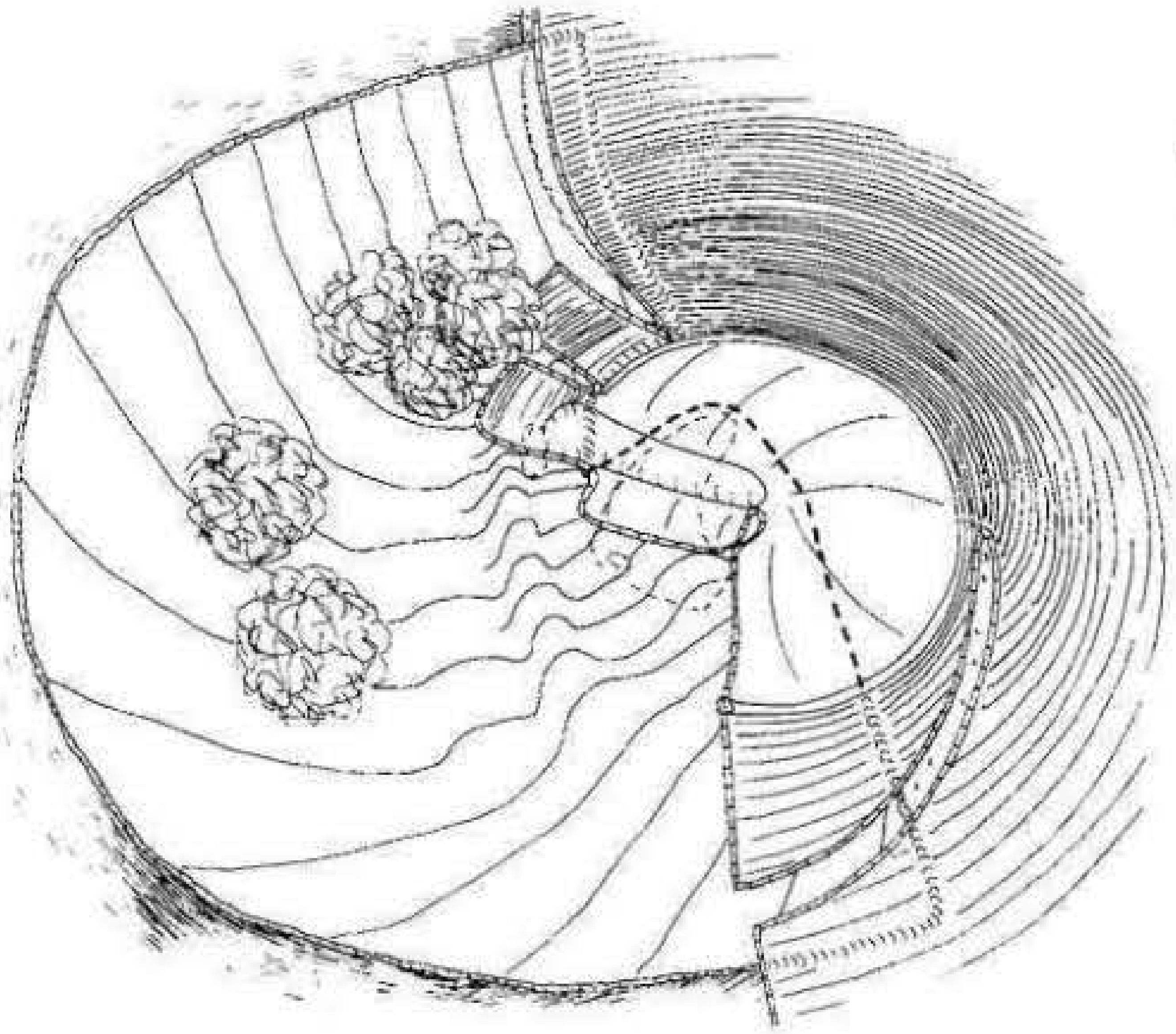


Fig. **707** The epithelial flaps are replaced, and Gelfoarr balls are fixing the fascia to the tegmen tympani

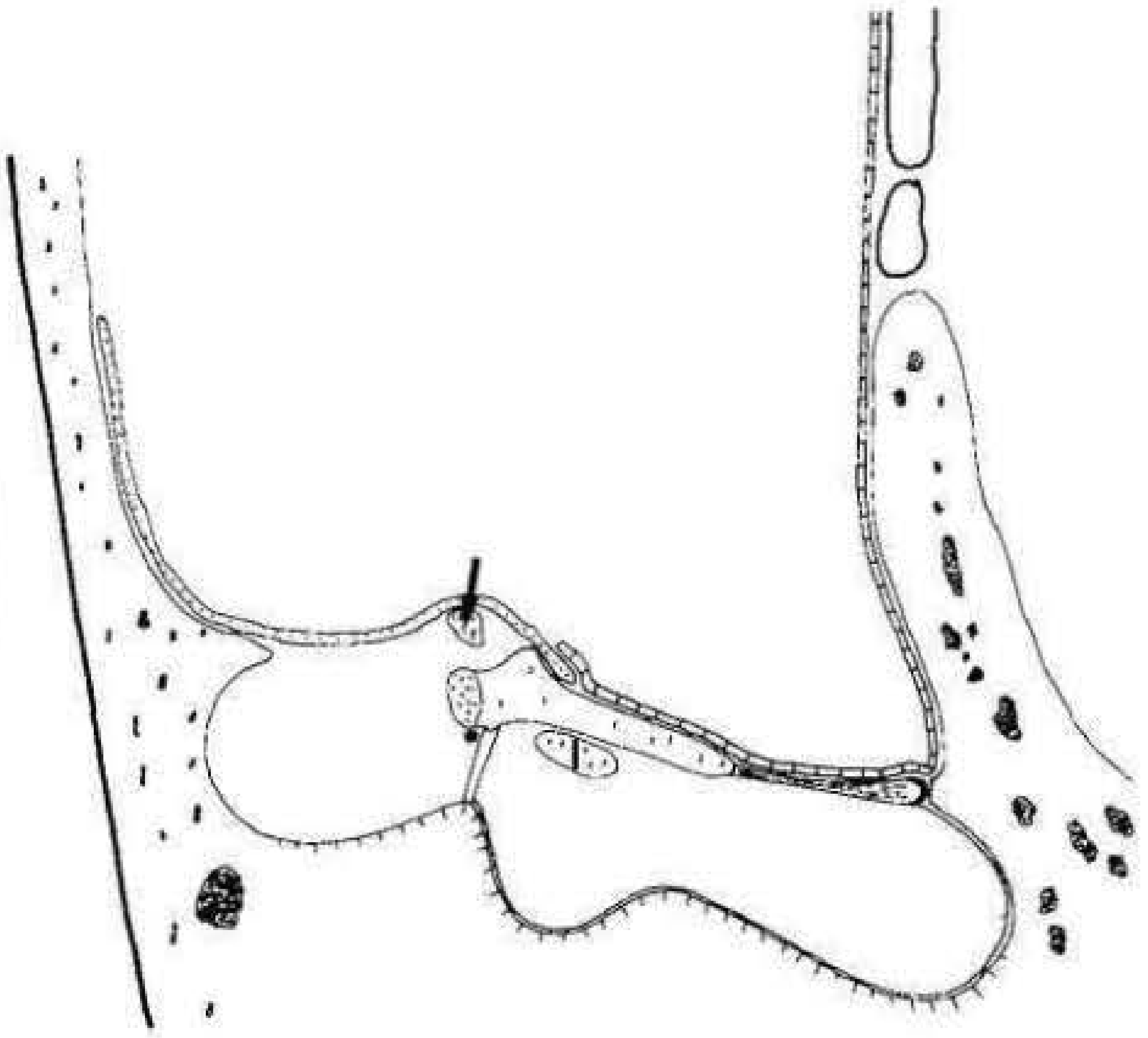


Fig. **708** Side view of the reconstructed and ventilated attic in a situation with a missing malleus head and intact bony bridge (arrow). Fascia is placed on the malleus handle, the preserved bridge, and the tegmen tympani. The short process of the incus (I) is located under the malleus

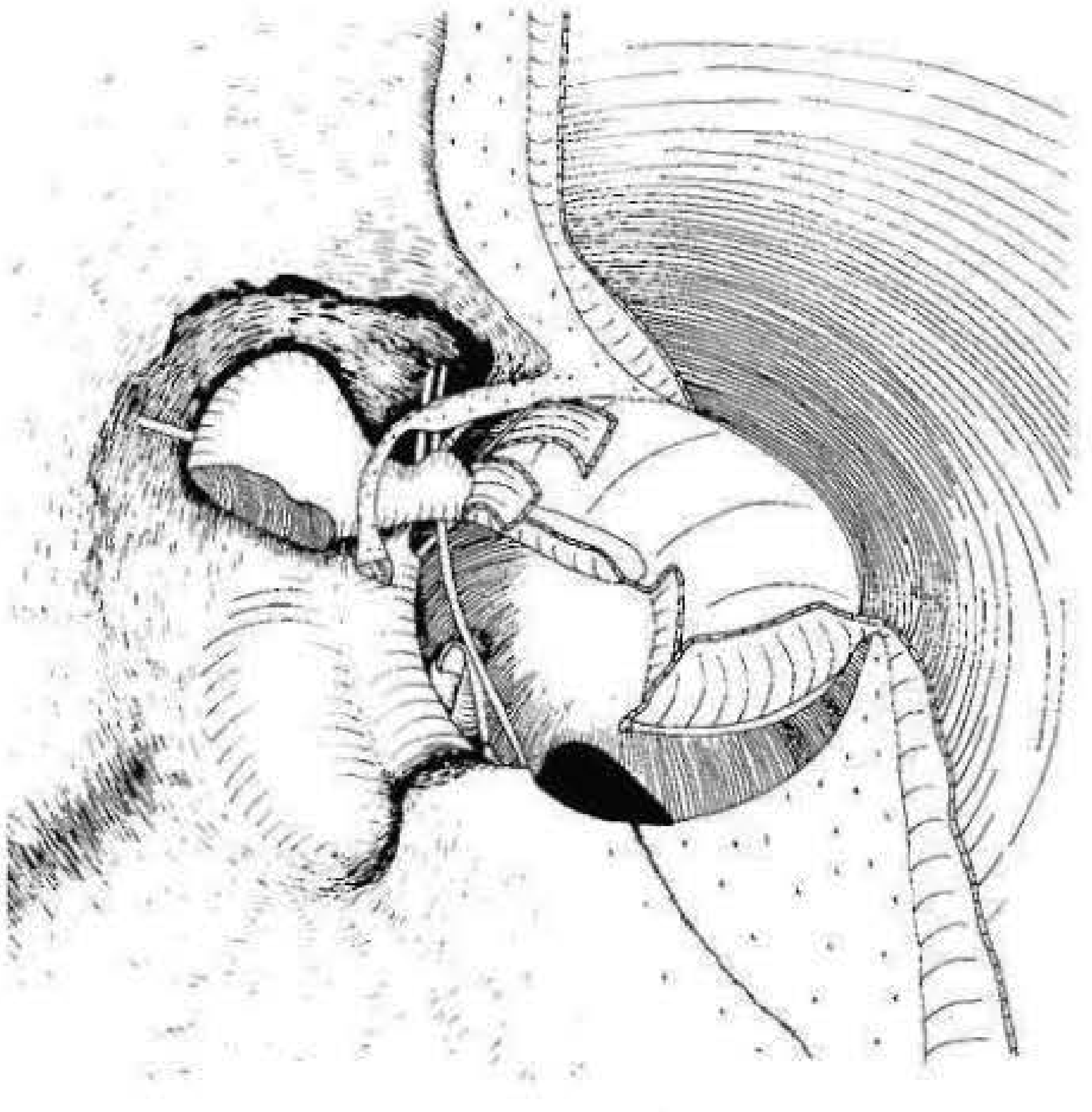


Fig. **709** **Partial preservation of the bony bridge in an endaural canal wall–down mastoidectomy.** The bridge is preserved anteriorly, providing good potential ventilation of the attic

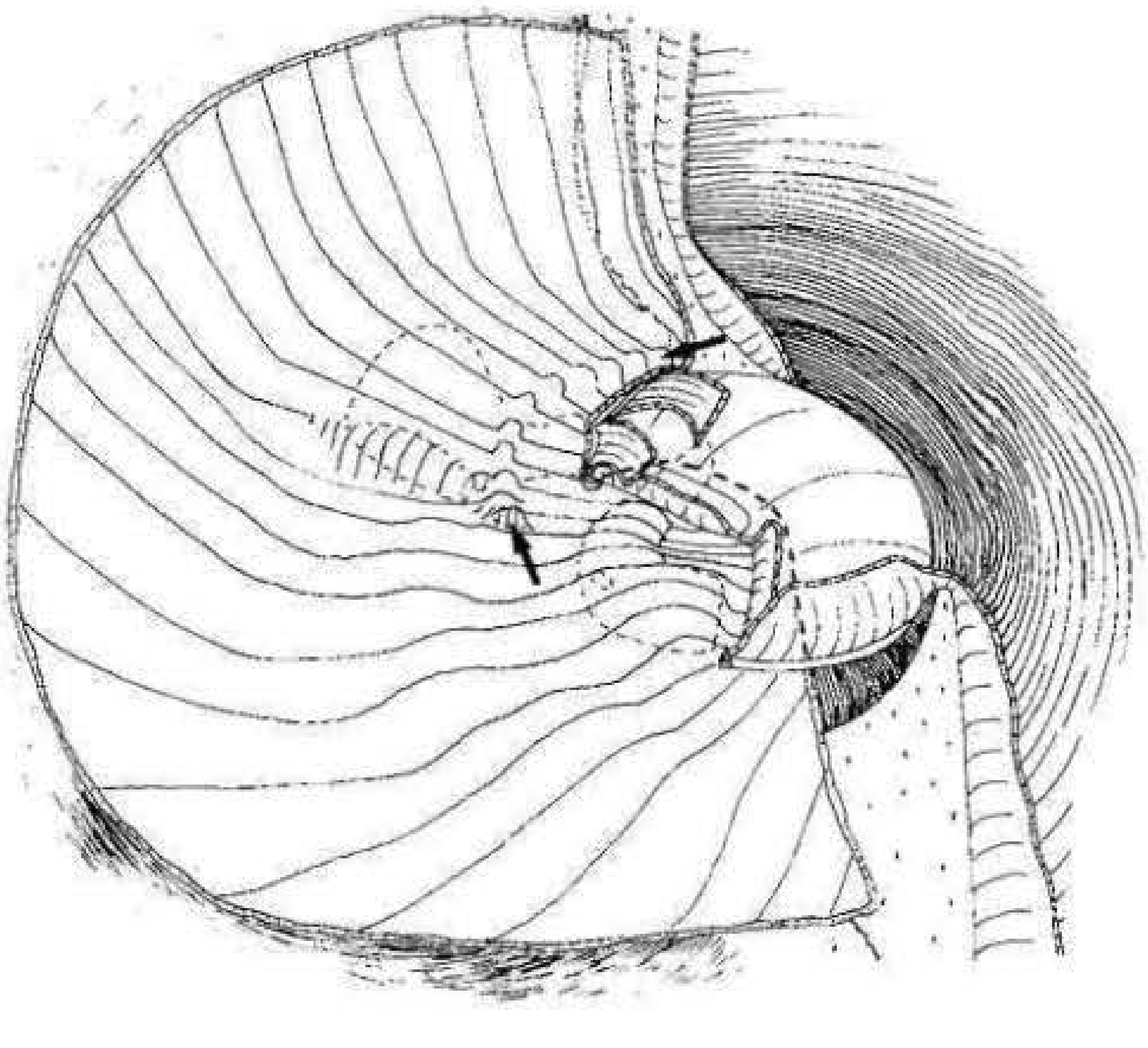


Fig. **710** **Reconstruction of the attic.** The incus is inter posed under the malleus handle, and the fascia is placed under the drum remnant and on top of the preserved bridge (arrows). The fascia covers the tegmen tympani

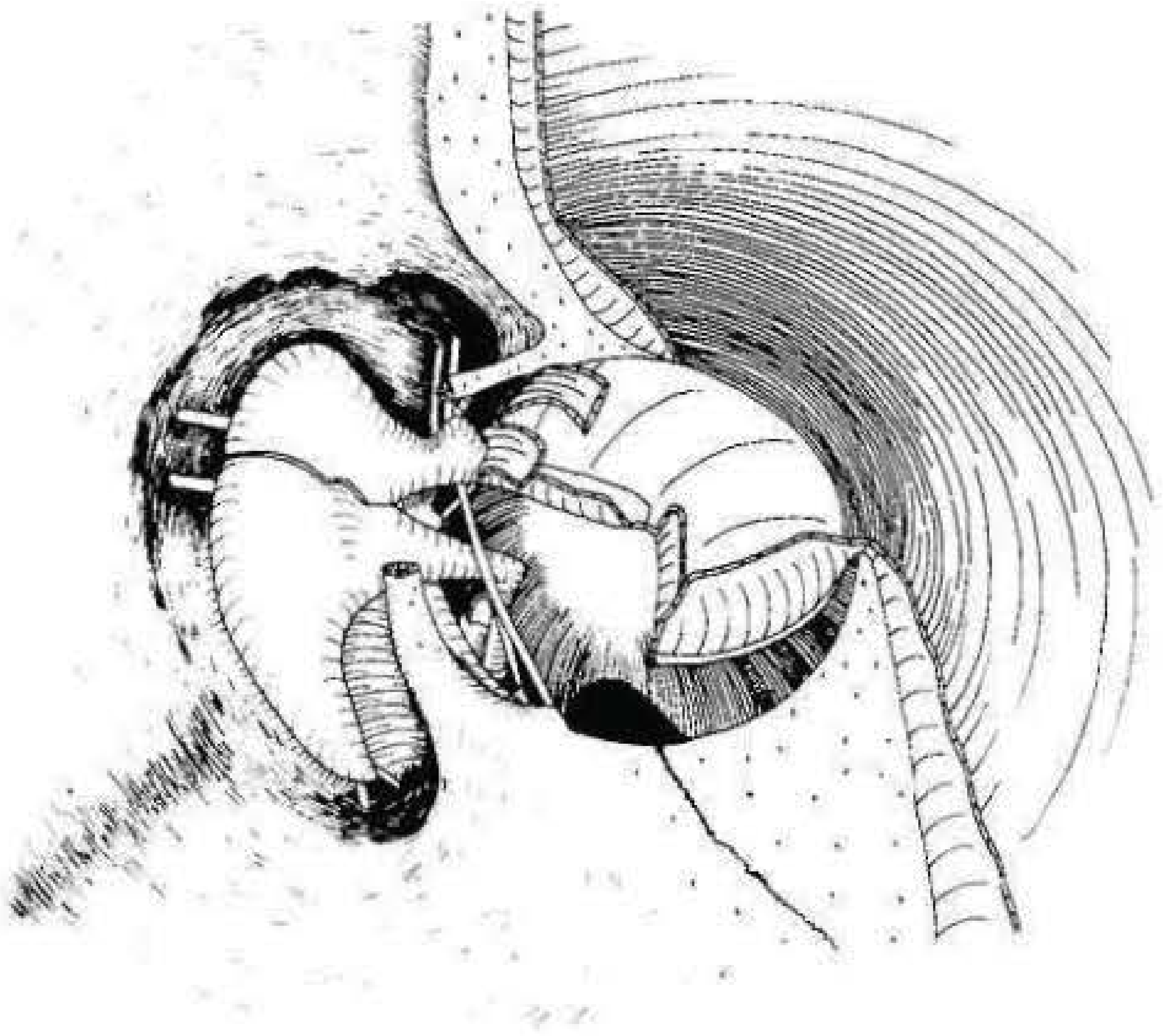


Fig. **711** A situation with partial preservation of the bridge in an endaural canal wall–down mastoidectomy with an intact ossicular chain. The central part of the bridge is resorbed

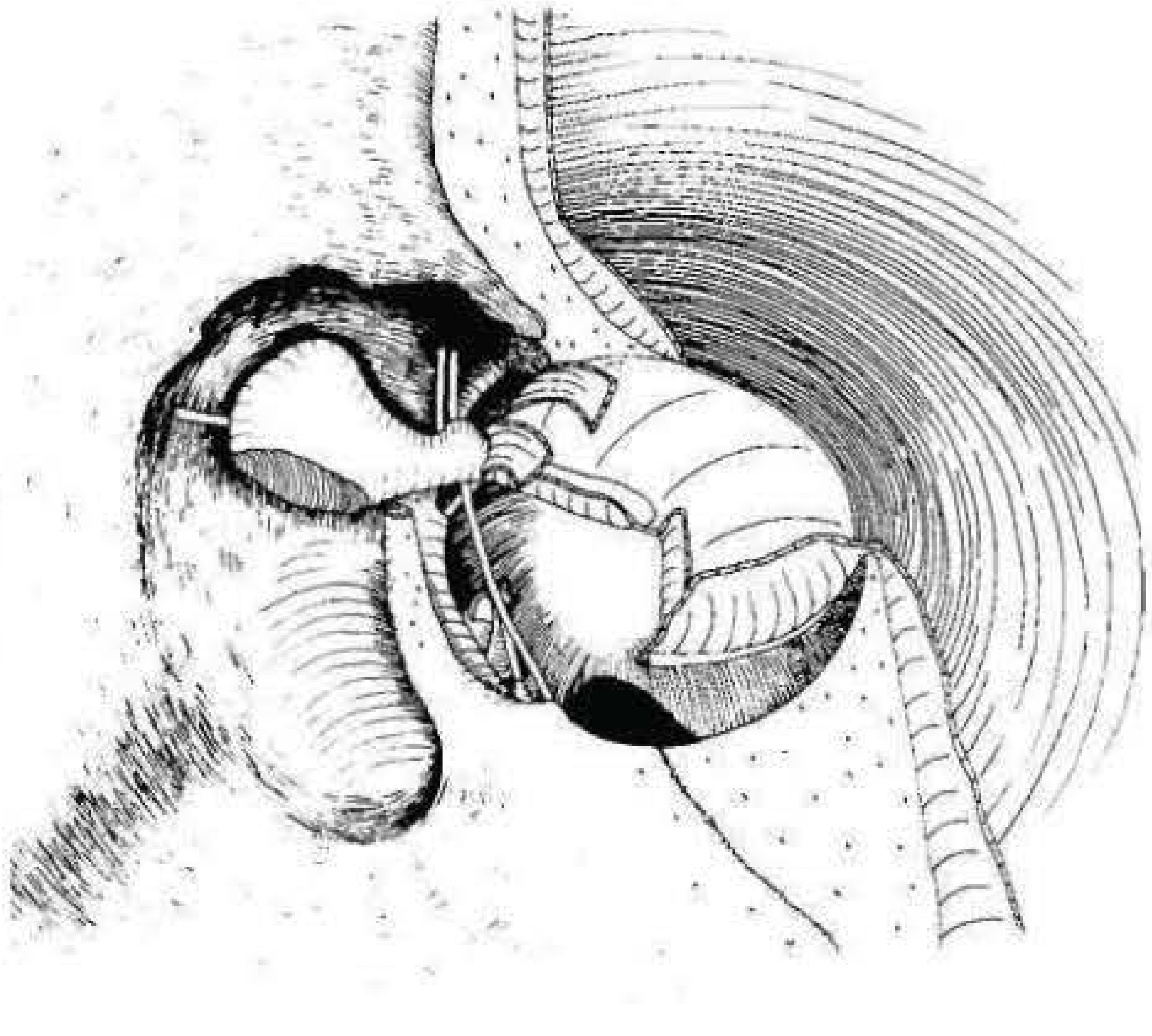


Fig. **712** Partial preservation of the posterior half of the bridge in a canal wall–down mastoidectomy

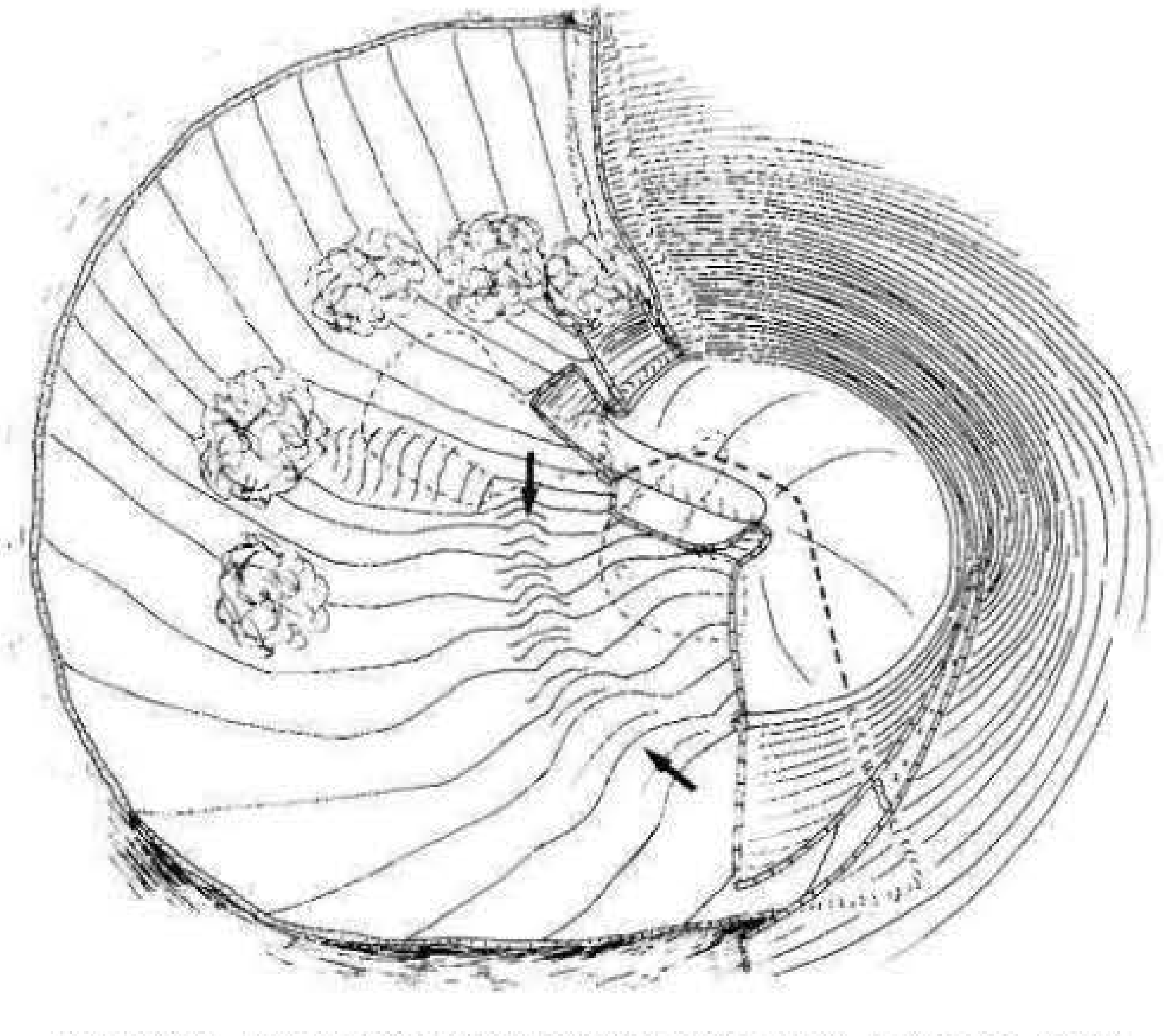


Fig. **713** Reconstruction of the attic with a fascia graft placed under the drum remnant and on top of the preserved posterior part of the bridge (arrows). The skin flaps are replaced, and the fascia is fixed to the tegmen tympani

The Paparella Intact Bridge Tympanomastoidectomy

Paparella (Paparella and Yung 1983, 1984) has introduced a special intact bridge technique that differs in some respects from the techniques described previously:

1. The preserved bridge is somewhat thicker and higher than usual (Fig. **714**). It provides a relatively high tympanic cavity.

2. An anterior tympanotomy with elevation of the anterosuperior part of the drum allows inspection of the tympanic cavity and mobilization of the drum laterally.

3. The malleus head is resected (Fig. **715**) and removed.

4. The tendon of tensor tympani muscle is cut, and the malleus handle is elevated laterally (Fig. **716**).

6. A PORP or TORP is placed between the head of the stapes and the mobilized malleus handle, and covered with a cartilage slice (Fig. **716**).

6. To prevent potential retraction, a piece of muscle, fibrous tissue, or any other mesenchymal tissue, obliterates the anterior attic as a free graft (Fig. **716**), and blocks its connection to the epitympanic sinus and Eustachian tube.

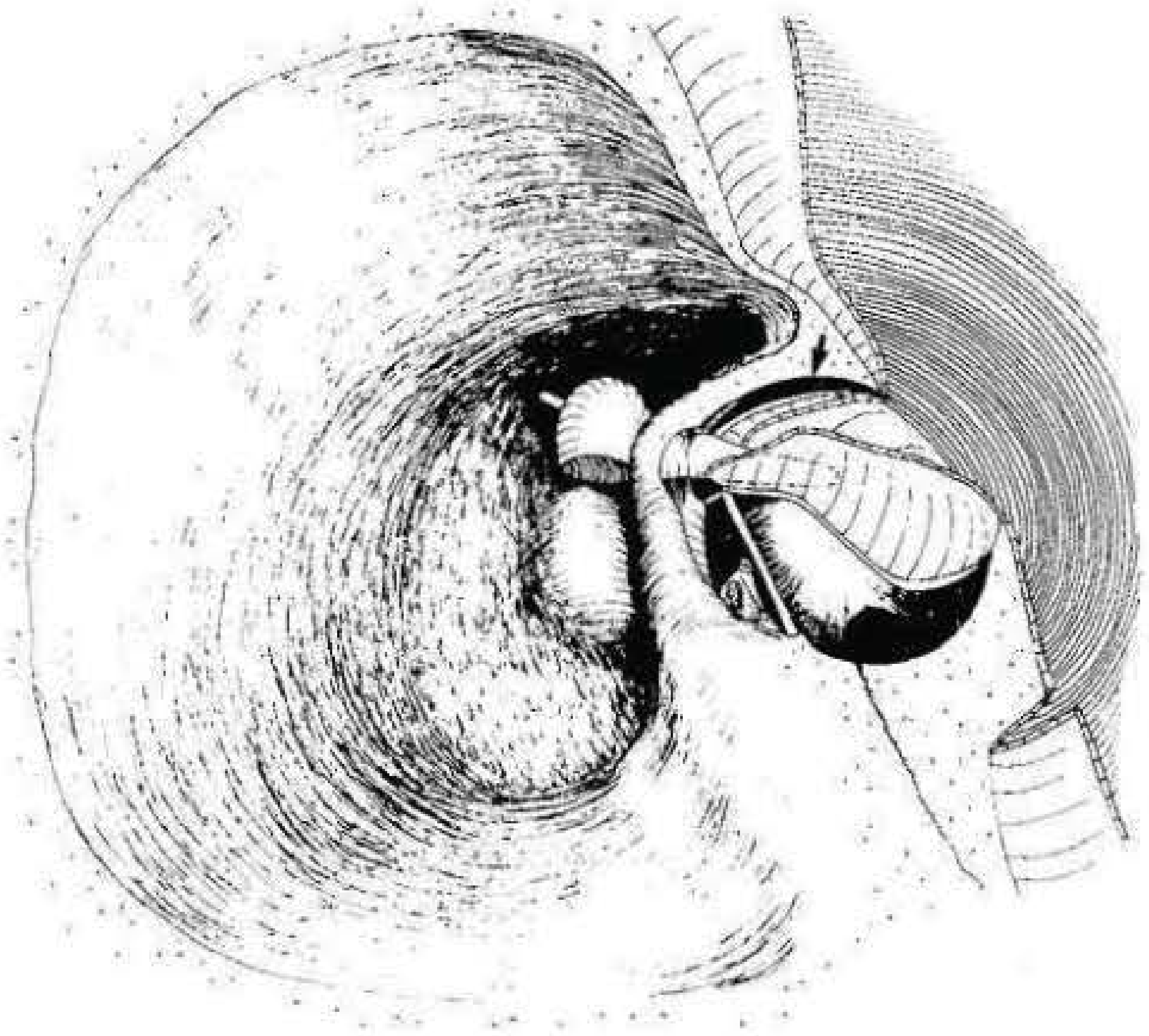


Fig. **714** **The Paparella intact bridge tympanomastoidectomy.** An endaural canal wall–down mastoidectomy is performed, the mastoid cells are exenterated, the incus is removed, and a relatively thick and high bridge is preserved. Anteriorly, an anterior tympanotomy is performed by elevating the fibrous annulus, allowing inspection of the anterior tympanum (arrow)

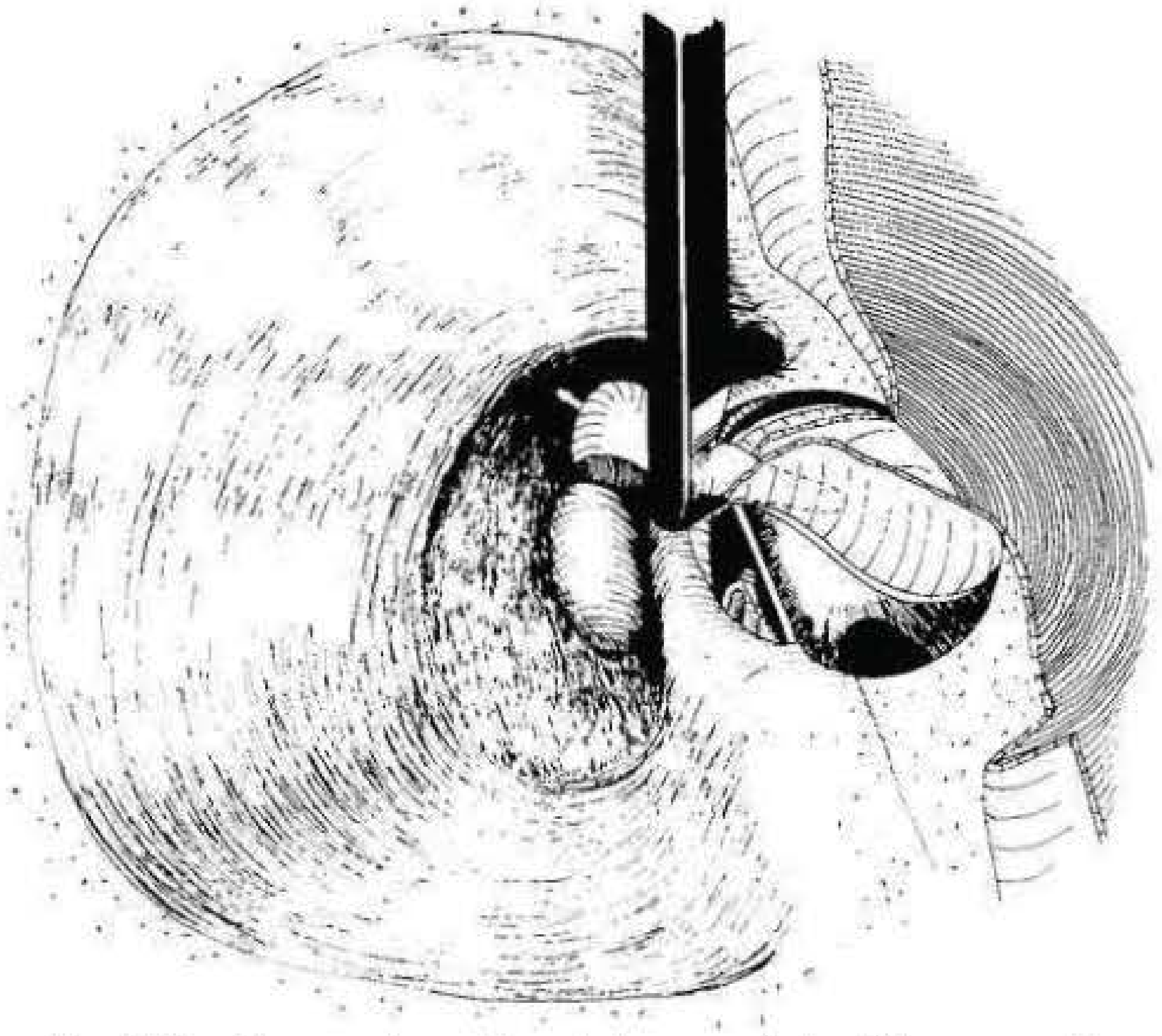


Fig. **715** The malleus head is resected with a punch, placed between the preserved bridge and the tendon of the tensor tympani muscle

7. A large fascial graft, placed under the drum and over the bridge, continues medially onto the medial attic wall, thus including the attic in the open cavity (Figs. **717, 718**).

8. The principle of the technique is the creation of a high tympanic cavity with a firm and relatively thick drum, and an open mastoid cavity that is covered with a split-skin graft in a second-stage operation approximately three weeks after the primary surgery (Goycoolea et al. 1989).

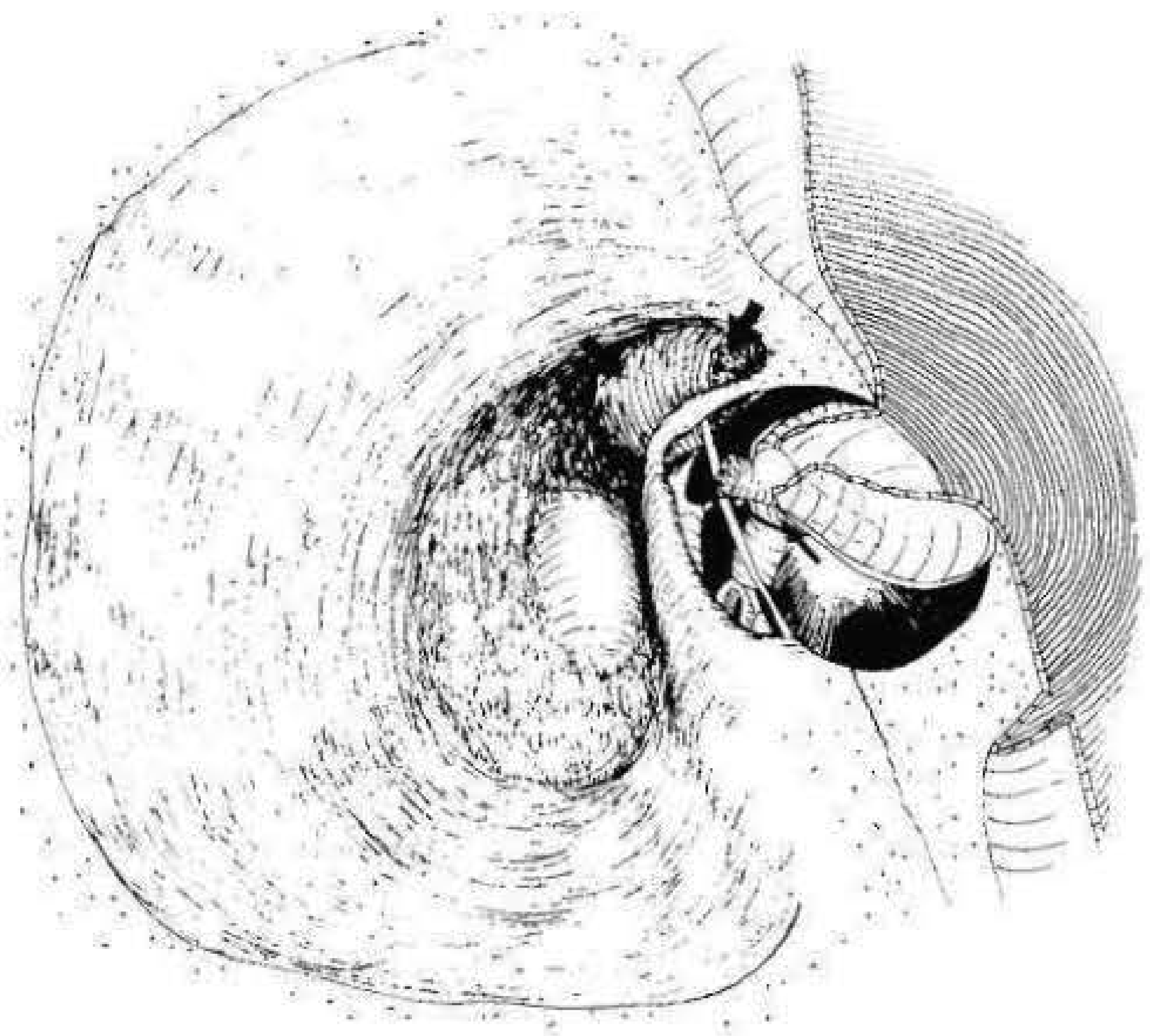


Fig. **716** **Obliteration of the anterior attic** with a piece of muscle (thick arrows) as a free graft. The malleus is resected, and the tendon of the tensor tympani muscle is cut, allowing elevation of the drum with the malleus handle and placement of a PORP with a cartilage slice (thin arrow) between the head of the stapes and the malleus handle

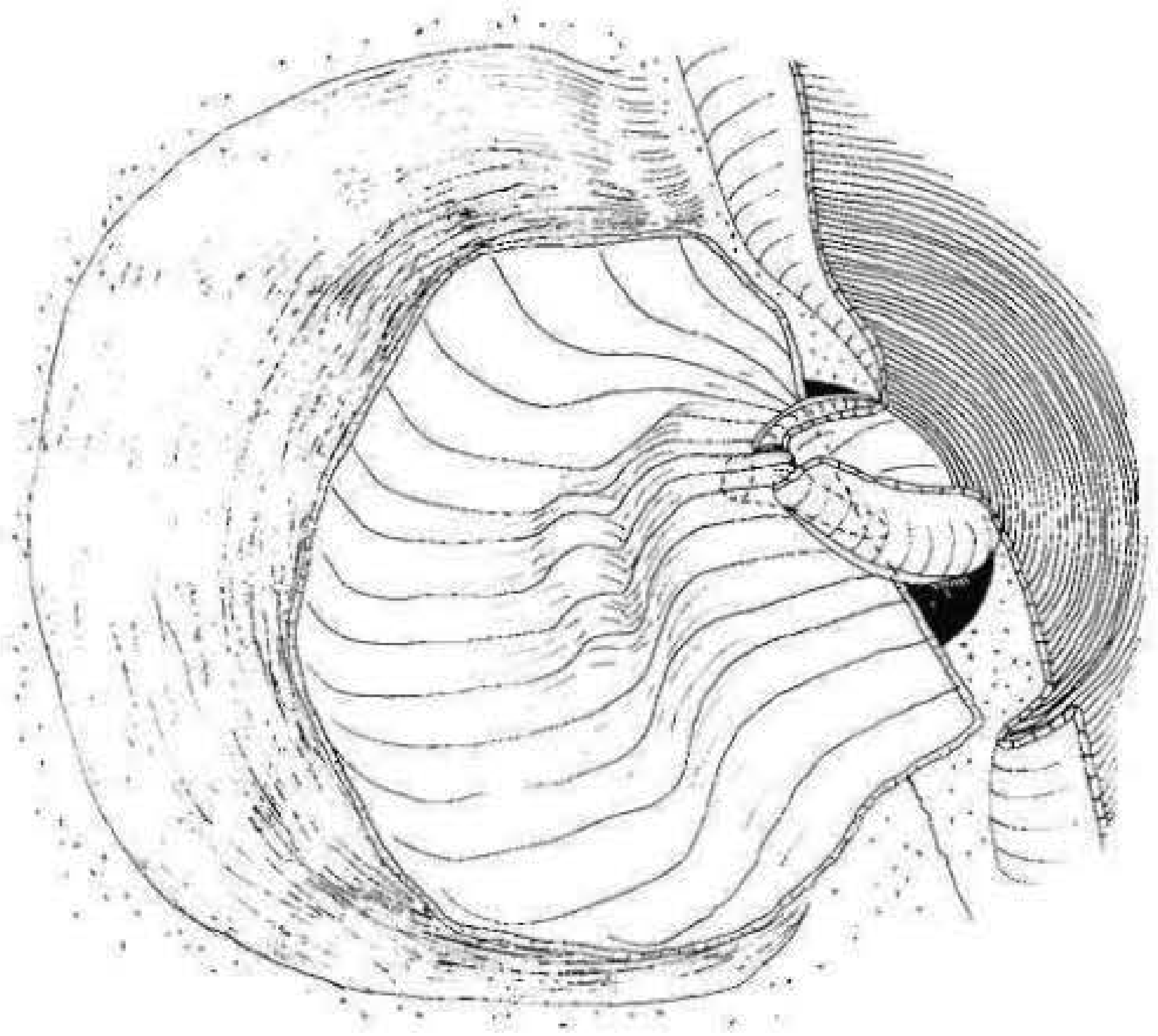


Fig. **717** **Reconstruction of the drum and the attic.** A large fascial graft is placed under the drum remnant and on top of the malleus handle and short process of the malleus, as well as on the preserved bridge. Then the fascia runs medially, covering the medial wall of the attic and the lateral semicircular canal. The fascia also covers the medial wall of the cavity

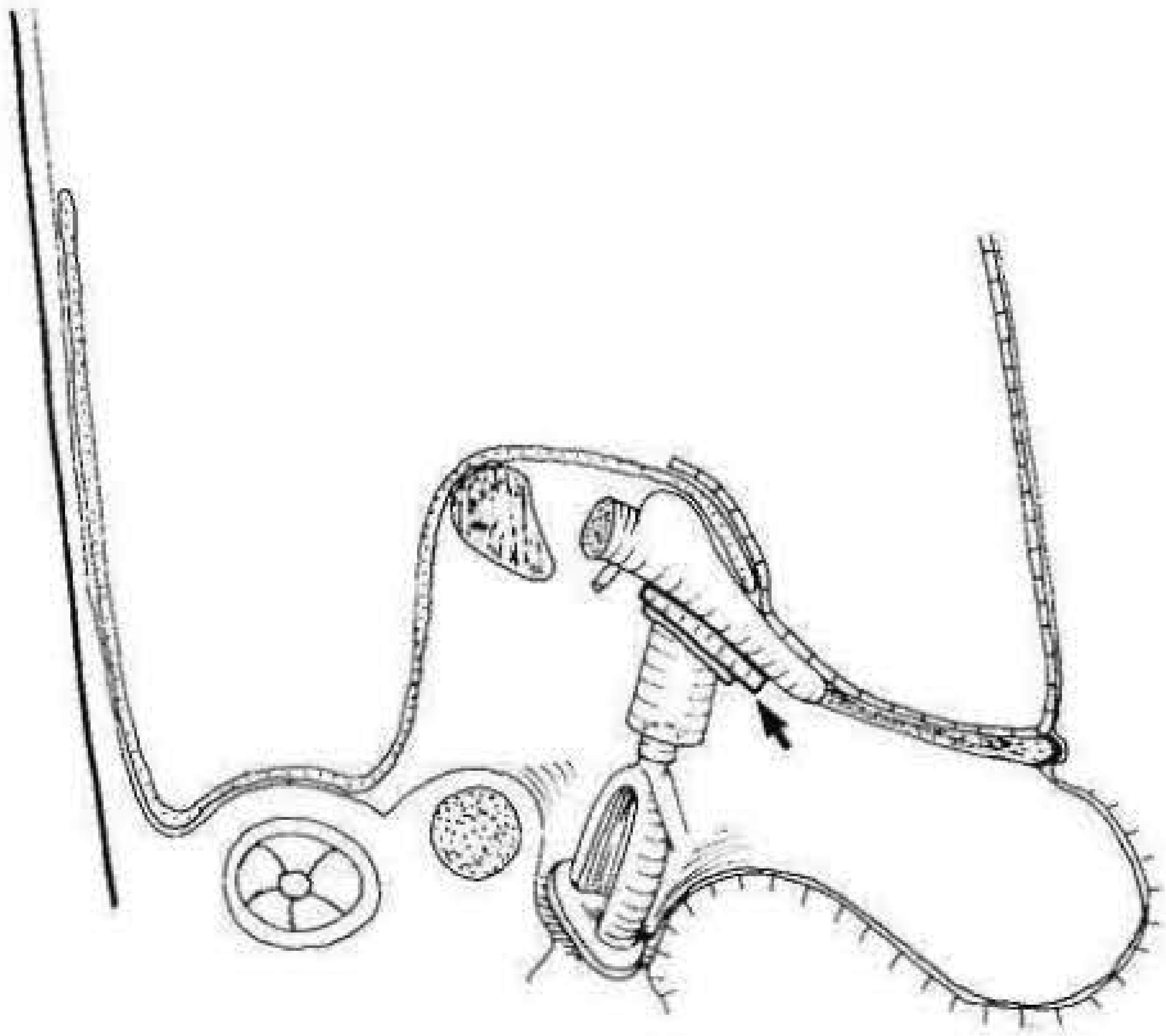


Fig. **718** Side view of the reconstruction of the tympanic cavity in Paparella's intact bridge mastoidectomy.

Part II

Reconstructions

14 Classification of Reconstruction Methods

All types of mastoidectomy apart from simple mastoidectomy require some form of reconstruction, either of the drum, the ossicular chain, or the ear canal.

In canal wall–up mastoidectomy, the bare bone of the cavity wall will hopefully become covered by mucosa behind the preserved ear canal wall, or covered by mesenchymal tissue in cases of obliteration.

In canal wall–down mastoidectomy, the same situation can be achieved, i. e., reconstruction of the ear canal wall and ventilation or obliteration of the cavity. In addition, in an open technique the cavity wall can be covered with skin, either ear canal skin or heterotopic skin.

There is no generally accepted classification or terminology for the many methods of reconstruction. Austin used the term *mastoidplasty* (Austin and Sanabria 1962, Austin 1964) for reconstruction of the tympanic cavity and obliteration of the cavity with pedicled flaps, but this term never became popular. Rambo (1958, 1969) used the term *musculoplasty* for a similar procedure. Schiller used the term *mastoid osteoplasty* for obliteration of the cavity with bone (Schiller and Singer 1960, Schiller 1961, Schiller 1963). Some terms are even confusing, e. g., the use of the term *meatoplasty* for reconstruction of the posterior ear canal wall (Müsebeck 1970). Many surgeons, including the present author, use the term *meatoplasty* for widening of the external auditory meatus with resection of the conchal cartilage in the creation of an open cavity (Shambaugh 1959, Saunders and Paparella 1971, Portmann 1979, Fisch 1980, Shambaugh and Glasscock 1980, Glasscock 1982, Sheehy 1988, and others). Some authors have used the term *meatomastoidplasty* for reconstruction of the defects of the bony ear canal wall. In order to avoid confusion with the term *meatoplasty* the present author has used the term *scutumplasty* for partial reconstruction of the posterior ear canal wall (Chapter 6).

Meatoplasty is also the term used for the creation of an ear canal in surgery for congenital atresia.

Miisebeck (1971) proposed a classification of antrum-mastoid operations, consisting of five types:

1. Antrostomy, denoting opening of the antrum, mainly for diagnostic purposes (Plester antroscopy) and for ventilation reasons (Fig. **719a**).
2. Mastoidectomy, describing preservation of the intact ear canal wall (Fig. **719b**).
3. Meatoplasty (or meatomastoidplasty) describing reconstruction of defects of the posterior bony ear canal wall (Fig. **719c**).
4. Mastoid obliteration after removal of the bony ear canal wall (Fig. **719d**).
5. Radical operation, describing an open cavity after removal of the bony ear canal wall (Fig. **719e**).

It is evident that such a classification into five types does not cover the demands of modern reconstruction methods of the middle ear and ear canal wall.

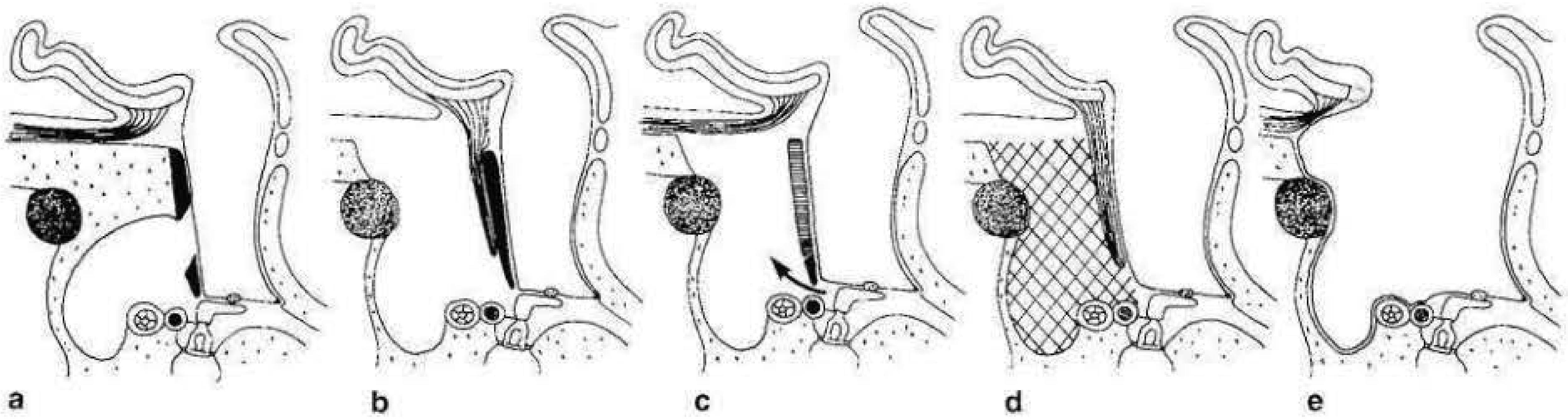


Fig. **719** **The classification of mastoidectomies and reconstructive methods proposed by Müsebeck. a** Antrostomy with opening of the antrum, leaving most of the ear canal intact. **b** Mastoidectomy with a preserved ear canal wall and ventilated cavity. **c** Meatoplasty. The ear canal is partly or totally removed, but reconstructed. The cavity is ventilated (arrow). **d** Mastoid obliteration after removal of the bony ear canal wall. **e** Radical operation with an open cavity

Another classification, including mastoidectomy types as well as their reconstruction, and dividing the procedures into atticotomy, atticoantrotomy, cortical mastoidectomy, tympanomastoidectomy, Bondy's operation, the conservative radical operation, and the classical radical operation, is also used. These procedures are defined and illustrated in Chapter 1 above, but this classification neither includes nor sufficiently describes the methods of reconstruction.

Some general terms have become widely used in connection with reconstruction, such as *open,* as opposed to *closed* techniques, indicating the *outcome* of the reconstruction. Another generally accepted classification is related to the *region* to be reconstructed.

Closed and Open Techniques

Recognizing that reconstruction of the middle ear cleft often cannot be performed as planned or desired, but is a compromise between various principles and methods; and recognizing that the outcome of a reconstruction technique does not always correspond to its intention, the author proposes a new flexible classification of open and closed techniques, allowing transition from the closed to the open technique. This classification also includes the situation in the attic.

The **closed technique** includes and describes all procedures required to *avoid a cavity.* However, there is a gradual transition to open techniques.

In *canal wall–up mastoidectomy* situations, the closed technique includes ventilation (repneumatization) of the cavity behind the preserved ear canal wall (Fig. **720a**), or total obliteration (Fig. **720b**), or partial obliteration of the cavity behind the preserved ear canal wall, with ventilation of the attic (Fig. **720c**).

In *canal wall–down mastoidectomy* situations, the closed techniques include the reconstruction of the ear canal wall with ventilation (Fig. **721a**) with total or partial obliteration of the cavity (Figs. **721b, c**). The outcome of the reconstruction of the ear canal wall with hard materials, such as bone or hydroxyapatite, closely resembles closed techniques after a canal wall–up mastoidectomy. The outcome of reconstructions of the ear canal wall with soft tissues, such as fascia, muscle or cartilage, or obliteration of the cavity with soft tissues without ear canal wall reconstruction, often includes a meatoplasty, resulting in some widening of the ear canal. Despite the meatoplasty and a widened ear canal, the obliterations are closed cavity techniques, mainly because a cavity is avoided.

The cavity including the attic can be totally obliterated (Fig. **722 a**), and the attic can be ventilated (Fig. **722 b**) or can remain as an open cavity (Fig. **722 c**). This latter technique is still a closed tech-

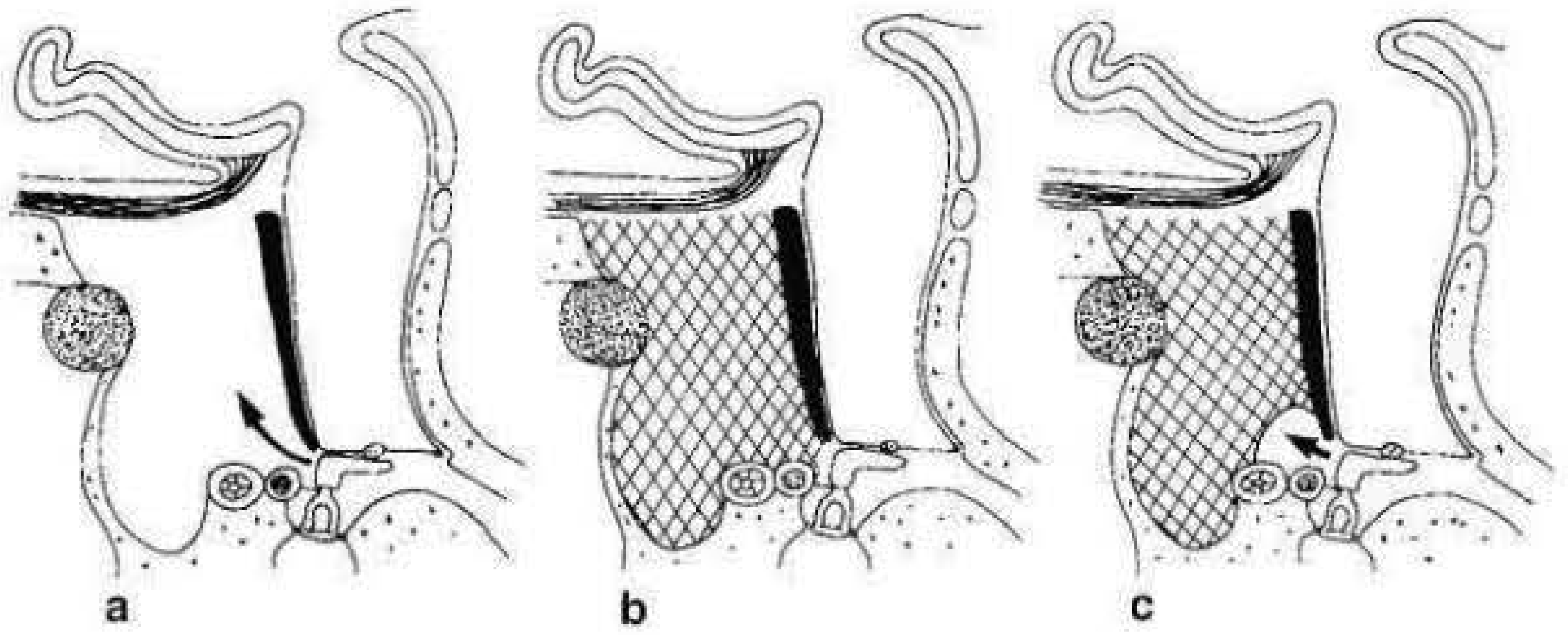


Fig. **720** **The classification of closed techniques after canal wall–up mastoidectomy. a** The ear canal wall is preserved and the cavity is ventilated (arrow). **b** The ear canal wall is preserved and the cavity is obliterated, including the attic. **c** The ear canal wall is preserved, the cavity is partly obliterated, and the attic is ventilated (arrow)

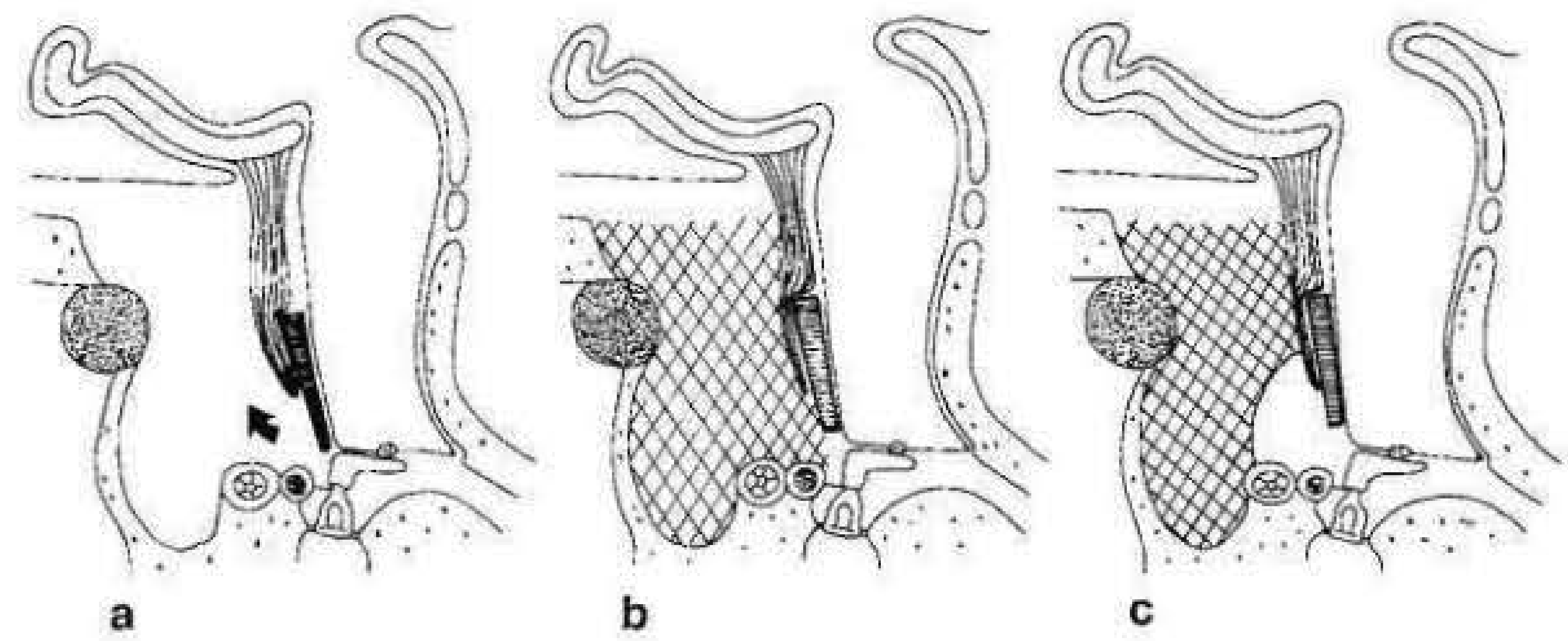


Fig. **721** **The classification of closed technique after a canal wall–down mastoidectomy with reconstruction of the ear canal wall. a** The ear canal is reconstructed, supported with a Palva flap, and the cavity is ventilated (arrow). **b** The ear canal wall is reconstructed and the cavity is completely obliterated. **c** The ear canal wall is reconstructed. The cavity is partly obliterated and the attic is ventilated

Fig. **722** **The classification of closed techniques after a canal wall–down mastoidectomy with obliteration and reconstruction of the ear canal with soft tissues, or with obliteration alone.** **a** The ear canal is widened and the cavity and the attic are obliterated. **b** The cavity is obliterated and the attic is ventilated (arrow). **c** The cavity is obliterated and the attic is open

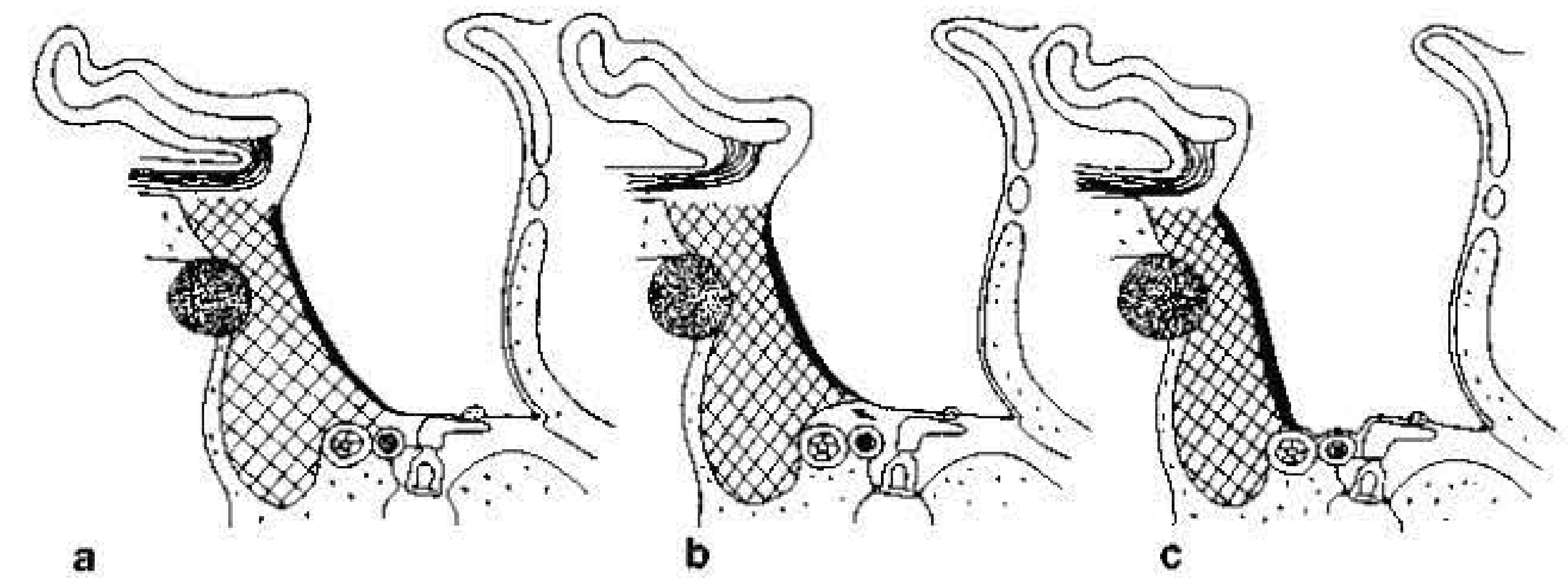
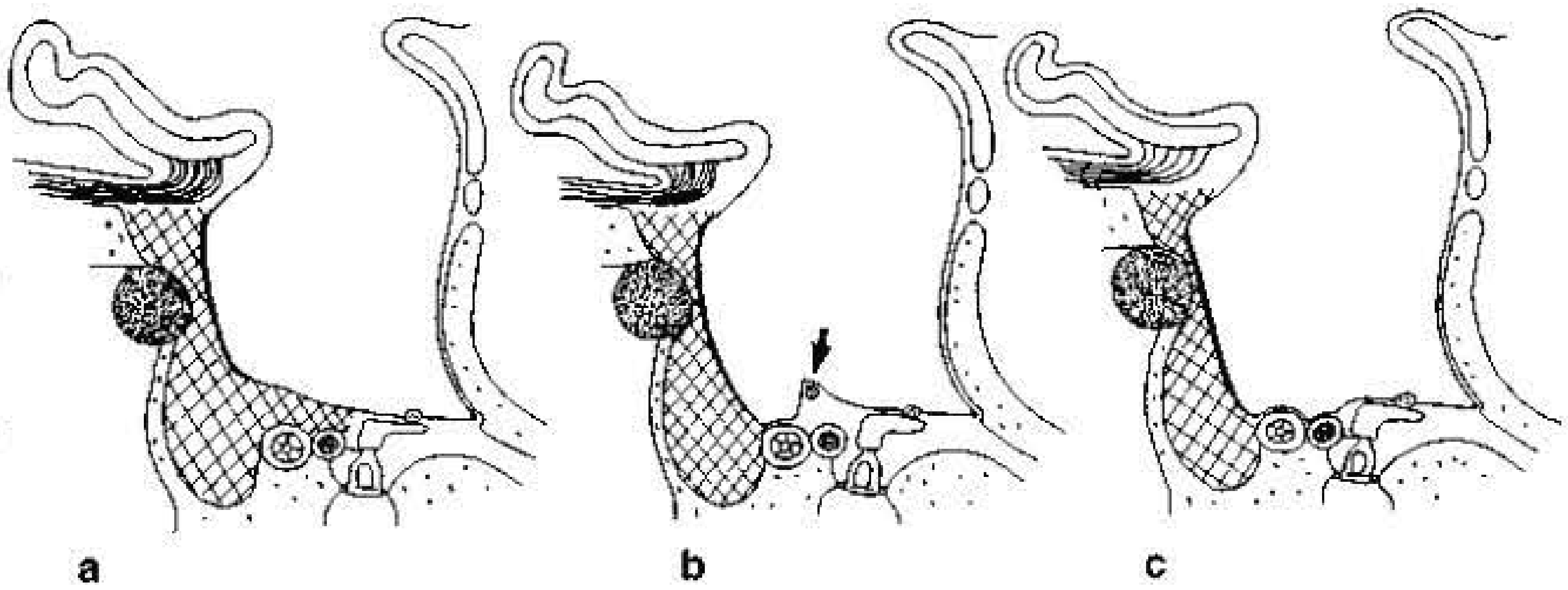


Fig. **723** **The classification of closed techniques after canal wall–down mastoidectomy with obliteration of the cavity with soft tissue and some meatoplasty.** The ear canal is considerably widened. **a** The cavity and the attic are obliterated. **b** The cavity is obliterated, and the attic is ventilated behind a preserved bridge (arrow). **c** The cavity is obliterated and the attic is open. A gradual transition to the open technique is evident



nique, because a cavity is avoided, even though it includes some elements of the open technique, e. g., the meatoplasty with widened ear canal and the open attic.

If the ear canal is further widened, then despite an obliteration the result increasingly resembles an open technique (Fig. **723**). The same is the case if less extensive obliteration is performed. Large obliterated "cavities" often occur some years after obliteration. The cavities gradually become larger due to atrophy of the obliterating material, particularly muscle, or fibroplasia in the cartilage used for obliteration, or both.

The **open technique** is defined as resulting in a cavity, often combined with a meatoplasty, either with no attempt to obliterate the cavity (Fig. **724a**), or with partial cavity obliteration alone (Fig. **724b**) e. g., of the perilabyrinthine space or the mastoid tip. The attic is usually part of the open cavity, but it can be ventilated (Fig. **724**c) or obliterated (Fig. **724d**).

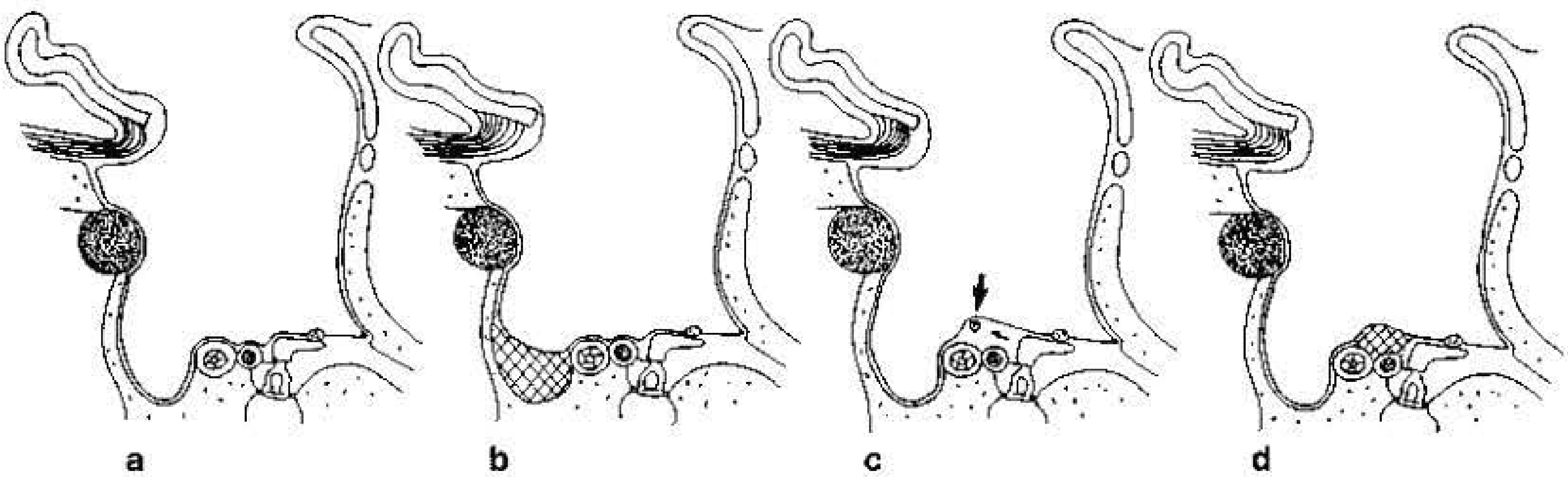


Fig. **724** **The classification of open techniques after canal wall–down mastoidectomy.** **a** The entire cavity, including the attic, is covered with skin. **b** The perilabyrinthine part of the cavity is partially obliterated. **c** The attic is ventilated behind a preserved bridge (arrow), and the remaining cavity is open. **d** The attic is obliterated, and the remaining cavity is open

The latter situation is also defined as an open cavity technique because the cavity is still not avoided.

This classification into closed and open techniques according to the outcome of the reconstruction takes the *degree of obliteration* into consideration for several reasons:

1. In canal wall–down mastoidectomy, the primary obliteration of the cavity is seldom complete, even if such an obliteration is desired and performed. A small cavity is often the immediate postoperative result (Tos 1969, 1977, 1978 b). Widening of the ear canal in the form of a small meatoplasty is therefore, in the author's opinion, an important and necessary improvement of an obliteration technique.

2. The size of the primarily obliterated cavity when soft tissue is used increases with time, making the degree of obliteration less and less complete. Meatoplasty with widening of the ear canal is increasingly necessary, and the closed technique becomes an open technique during the increase in the cavity size.

3. In most previous open radical cavities reconstructed into a closed cavity using obliteration techniques, a meatoplasty was originally performed. All these closed techniques thus already have a widened ear canal and resemble the situation illustrated in Figures **722** and **723**.

The four groups of closed cavity techniques can be summarized as follows:

1. Closed technique in *canal wall–up* mastoidectomy with ventilation or obliteration of the cavity (Fig. **720**).
2. Closed technique in *canal wall–down* mastoidectomy with reconstruction of the ear canal wall and ventilation or obliteration of the cavity (Fig. **721**).
3. Closed technique in *canal wall–down* mastoidectomy with cavity obliteration (Fig. **722**) and ear canal reconstruction using soft tissues, subdivided into an obliterated, ventilated, or an open attic.
4. Closed technique in *canal wall–down* mastoidectomy with cavity obliteration, subdivided into an open, ventilated, or obliterated attic (Fig. **723**).

After reconstruction of the ear canal wall with solid material and obliteration with soft tissues, atrophy of the obliteration material leads to the formation of a retraction pocket (Fig. **725**), similar to the retraction pockets seen in canal wall–up mastoidectomies (Chapter 6). This is also the result if ventilation of the cavity behind the reconstructed ear canal is disturbed (Fig. **720a**). After ear canal wall reconstruction and obliteration with soft tissues, the atrophy of the obliteration material leads to diffuse retraction of the entire soft ear canal wall and results in a small cavity with a widened ear canal (Fig. **726**).

This classification does not describe *how* the cavity has been obliterated and the ear canal wall reconstructed, but indicates whether the ear canal has been reconstructed with solid tissue or not. The various surgical methods used to achieve the closed or open techniques are described separately.

As long as the classification into closed and open techniques is related to the situation pertaining to cavity or noncavity conditions, the classification is simple. However, if the various conditions in the attic are included, then the classification becomes complicated, with many variations. The various methods of reconstructing the attic used, and their relation to reconstructions of the tympanic cavity, therefore have to be subclassified separately in order to understand the techniques being used.

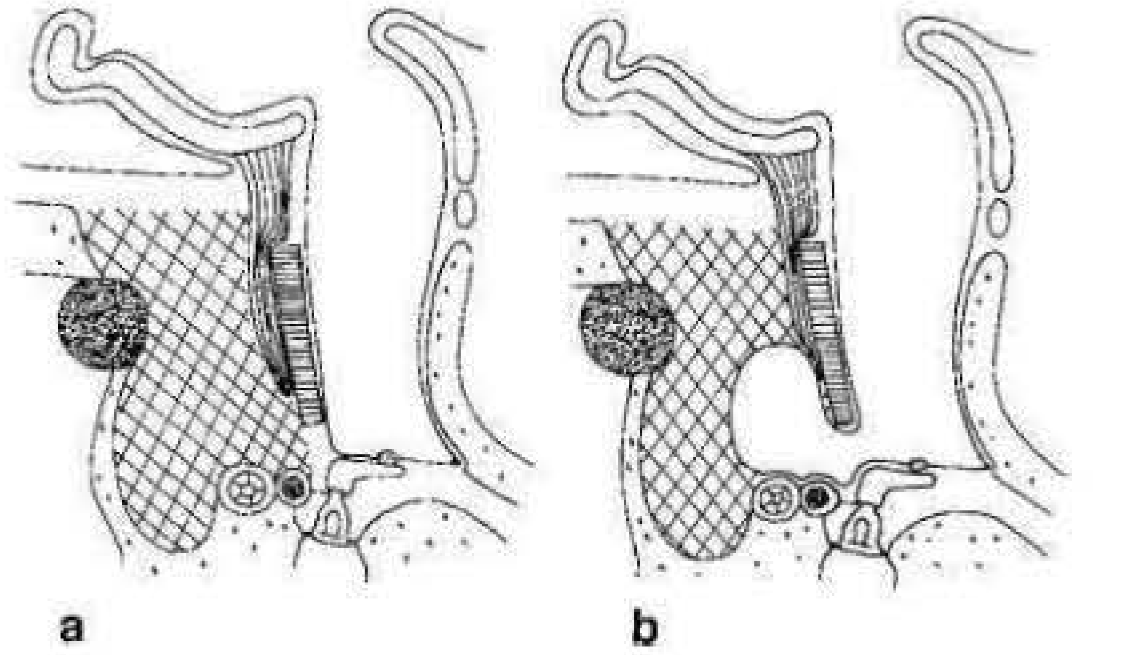


Fig. **725** **Reconstruction of the ear canal with hard tissue and obliteration of the cavity with soft tissue.** **a** Early postoperative condition. **b** Late after the operation, there is a retraction pocket behind the new ear canal when atrophy or fibroplasia of the obliterating material occurs

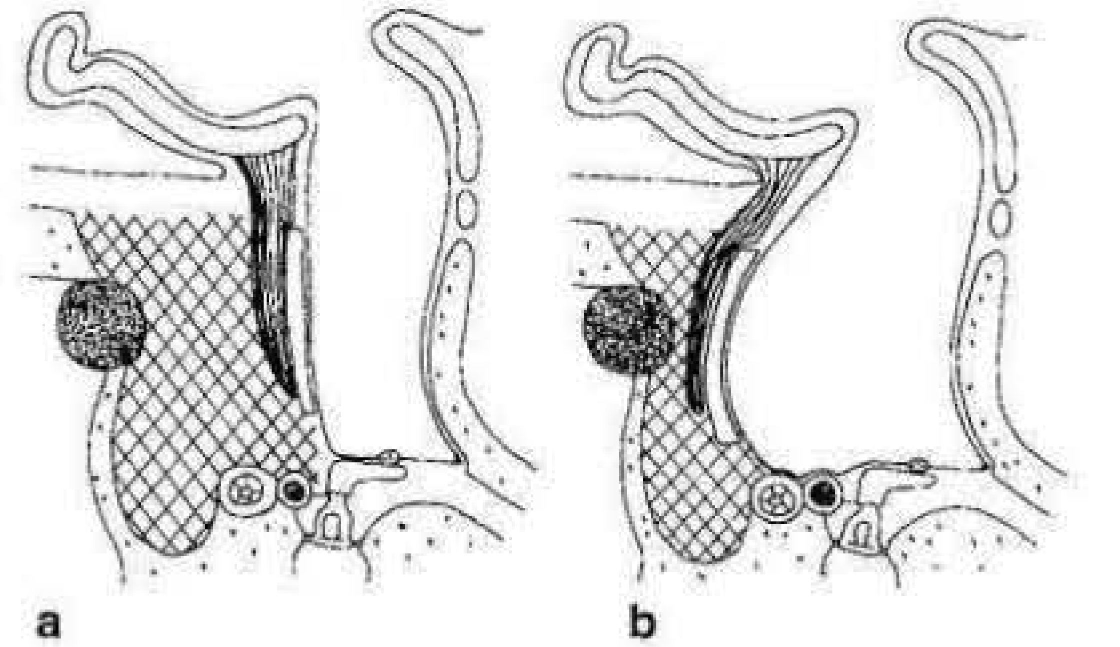


Fig. **726** **Obliteration of the cavity with soft tissues and reconstruction of the ear canal wall with soft tissue, including cartilage.** **a** Early after the operation. **b** Late after the operation, there is retraction of the entire ear canal wall due to atrophy of the obliterating material. The ear canal is wide, but the external meatus is narrow

Reconstruction of the Tympanic Cavity and the Attic

In most reconstructive procedures performed in connection with mastoidectomy, both ossiculoplasty and myringoplasty have to take place at the end of the operation. The procedures for myringoplasty and ossiculoplasty are described in Volume 1, but they have to be adapted to the type of mastoidectomy used and the conditions pertaining in the attic.

Myringo-Ossiculoplasty in Canal Wall–Up Mastoidectomy

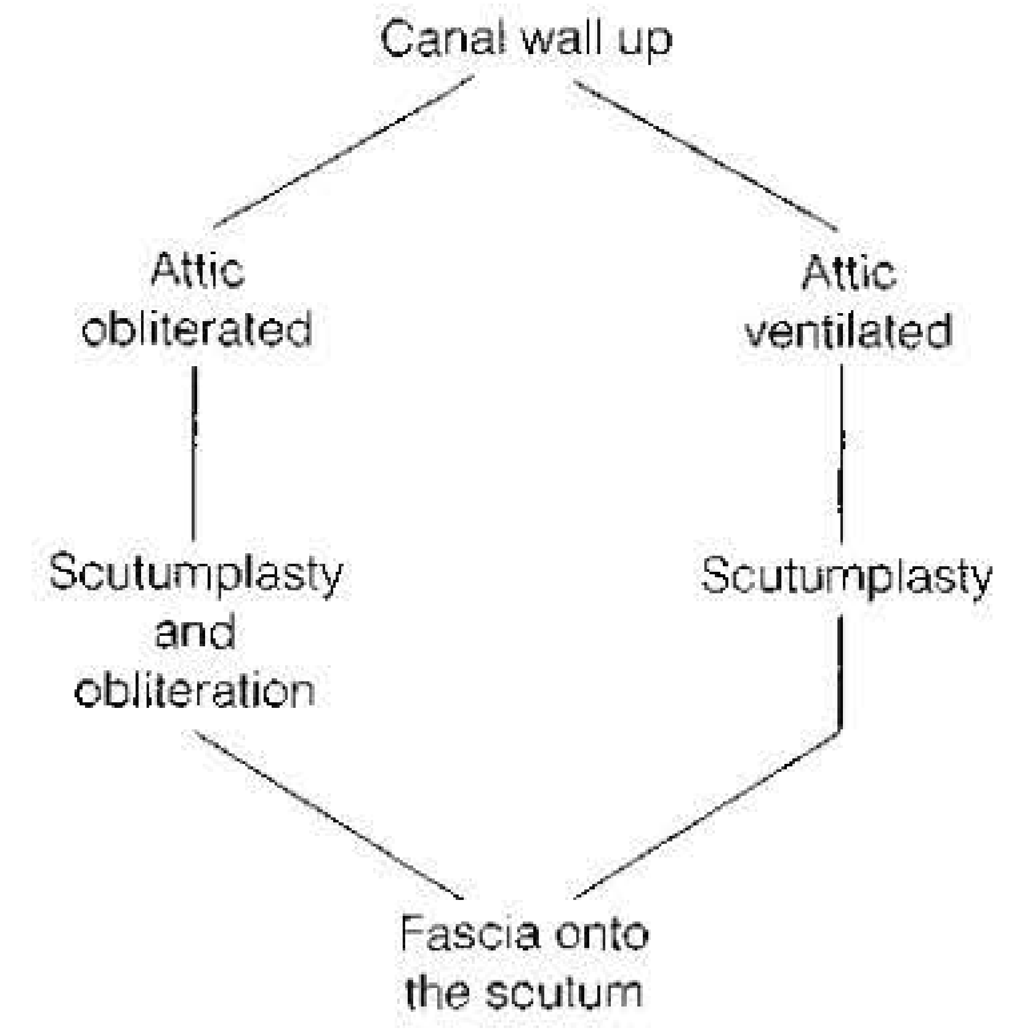
In *classical canal wall–up mastoidectomy,* the attic is ventilated or obliterated and the ear canal wall is preserved (Table **9**). In such cases, the myringoplasty and ossiculoplasty are practically the same as in cases with a normal ear canal wall: the fascia (or perichondrium or periosteum) closing the drum perforation is extended over the preserved or partially reconstructed posterior bony ear canal wall. The fascia is usually placed as an underlay graft, mainly because underlay grafting is easier in the retroauricular approach (Figs. **350–373**). In some situations, e. g., in tensa retraction cholesteatoma, onlay grafting can be a better option.

In *modified intact canal wall mastoidectomy,* the attic is ventilated or obliterated, and the ear canal wall is partly intact or is reconstructed. A large piece of fascia, placed as underlay graft, closes the drum perforation, covers the ossicles, and continues over the preserved bridge covering the atticotomy opening or the partially reconstructed ear canal wall (Figs. **438–441, 453, 462–464, 475–478**).

In the special techniques of *mobilization and temporary removal of the ear canal wall* as described in Chapter 8, the tympanic cavity is reconstructed and the attic is ventilated. The fascia is placed as an underlay graft and covers the osteotomies, either on the mastoid surface of the ear canal wall (Figs. **505, 506**) or on the meatal surface (Figs. **499, 516, 524**). In osteoplastic epitympanotomy (S. Wullstein) the fascia closes the drum perforation as an underlay graft, and continues over the replaced bony plate toward the mastoid tegmen, covering the osteotomies (Figs. **509, 510**).

In *tympanomeatoplasty with preservation of the bony bridge* (Wigand; Chapter 9), the attic is reconstructed and ventilated. The myringoplasty is performed using fascia as an underlay graft covering the reconstructed attic wall. As in ossiculoplasty, transposition of the malleus handle onto the head of the stapes is used (Figs. **545, 546**).

Table **9** Reconstruction of the attic and myringoplasty in canal wall–up mastoidectomy



In *transmeatal anterior atticotympanotomy and transcortical mastoidectomy* (Farrior; Chapter 10), the drum is reconstructed using fascia as an onlay graft, covered by ear canal skin in a sandwich technique (Vol. 1, pp. 182–3). Fascia also covers the attic and continues as far as the mastoid tegmen (Figs. **559–561**). Attic ventilation is intended.

The ossiculoplasty techniques are no different in canal wall–up mastoidectomy situations, which are the same as those described in Volume 1. The present author prefers autogenous ossicle, as the first-choice material, and cortical bone as the second-choice material. Both are easy to harvest and shape, as well as being free of charge.

Myringo-Ossiculoplasty in Canal Wall–Down Mastoidectomy

In myringoplasty and ossiculoplasty after canal wall–down mastoidectomy, the following points are of importance:

1. The method of reconstructing the attic.
2. The removal or preservation of the bony bridge.
3. The presence of the malleus head (or incus body) in the attic.

These conditions are intimately related to each other.

Reconstruction of the attic in cases with removal of the bridge. The attic can be left open (Table **9**), obliterated, or ventilated (Fig. **727**).

In the case of an *open attic* (Fig. **727**a) with a missing malleus head, the fascia closing the drum perforation continues directly around the neck of

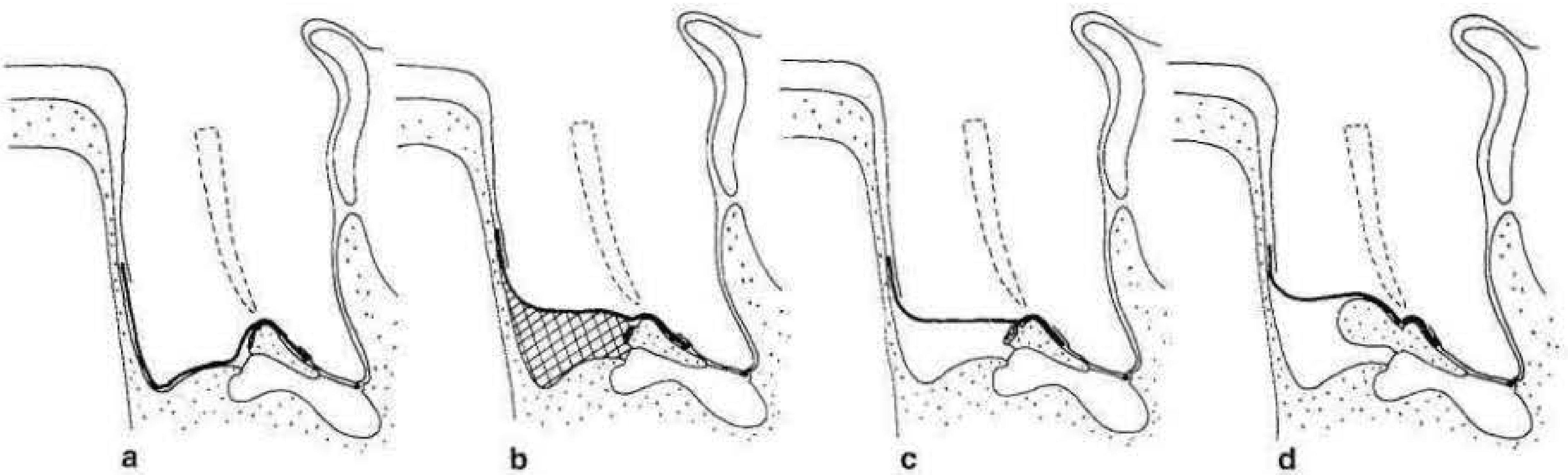
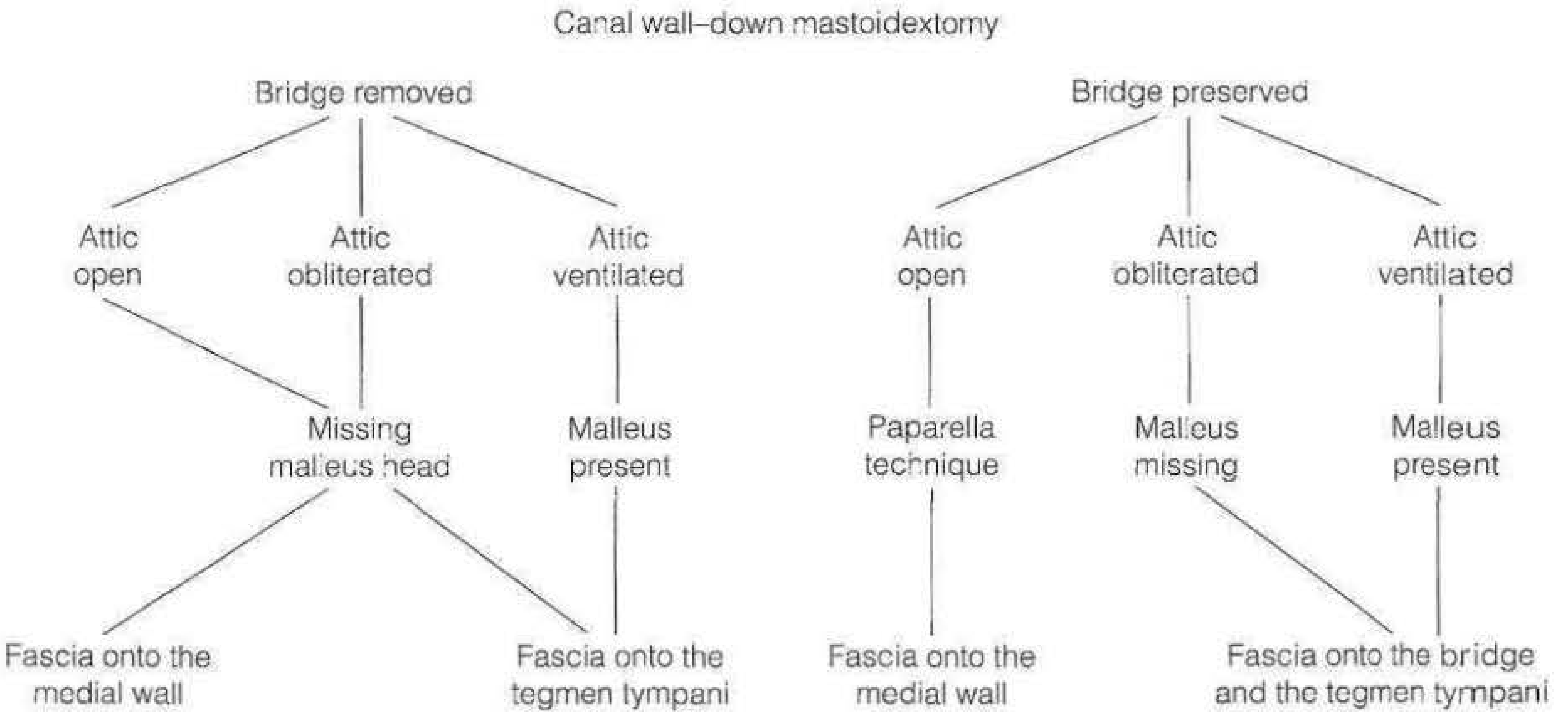


Fig. **727** **Reconstructions of the attic and myringoplasty after canal wall–down mastoidectomy with removal of the bridge. a** The attic is open, and fascia covers its medial wall to the tegmen tympani. The ear canal is widened. The dashed line represents the original position of the superior ear canal wall. **b** The attic is obliterated, and fascia covers the obliterating material. c The attic is ventilated in a case with a resected malleus head. The fascia goes directly onto the tegmen tympani. **d** The attic is ventilated in a case with a preserved malleus head (and possibly incus body, in a case with an intact ossicular chain). The fascia covers the head of the malleus and runs to the tegmen tympani

Table **10** Reconstruction of the attic and myringoplasty in canal wall–down mastoidectomy


Canal wall–down mastoidextomy
Bridge removed
Bridge preserved
Attic open
Attic obliterated
Attic ventilated
Attic open
Attic obliterated
Attic ventilated
Missing malleus head
Malleus present
Paparella technique
Malleus missing
Malleus present
Fascia onto the medial wall
Fascia onto the tegmen tympani
Fascia onto the medial wall
Fascia onto the bridge and the tegmen tympani

the malleus onto the medial wall of the attic and the tegmen tympani (Figs. **591, 610, 632, 639, 680, 682, 685**).

In the case of an *obliterated attic* (Fig. **727**b) either using muscle or cartilage (Figs. **690–692**), the fascia closes the drum perforation, covers the obliterating material, and continues over the tegmen tympani.

In a *ventilated attic* with a missing malleus head (Fig. **727c**), the fascia goes from the neck of the malleus to the tegmen tympani (Fig. **684**). In cases with a malleus head (Fig. **727d**), the fascia is supported by the malleus head as it passes over to the tegmen tympani (Figs. **602, 656, 675, 677, 678**).

In cases with no incus remnant in the posterior attic (Figs. **602, 656**), the fascia continues from an interposed graft or a columella down onto the eminence of the horizontal part of the facial nerve, reducing considerably the vibrating area of the drum and resulting in fibrous fixation of the ossiculoplasty. In cases with an intact ossicular chain, the conditions resulting in ventilation of the attic are optimal. The fascia covers the intact malleus and incus and passes onto the tegmen tympani (Figs. **585, 671, 673**).

Reconstruction of the attic with a preserved bridge (Table **10**). *An open attic* is achieved in Paparella's intact bridge tympanomastoidectomy

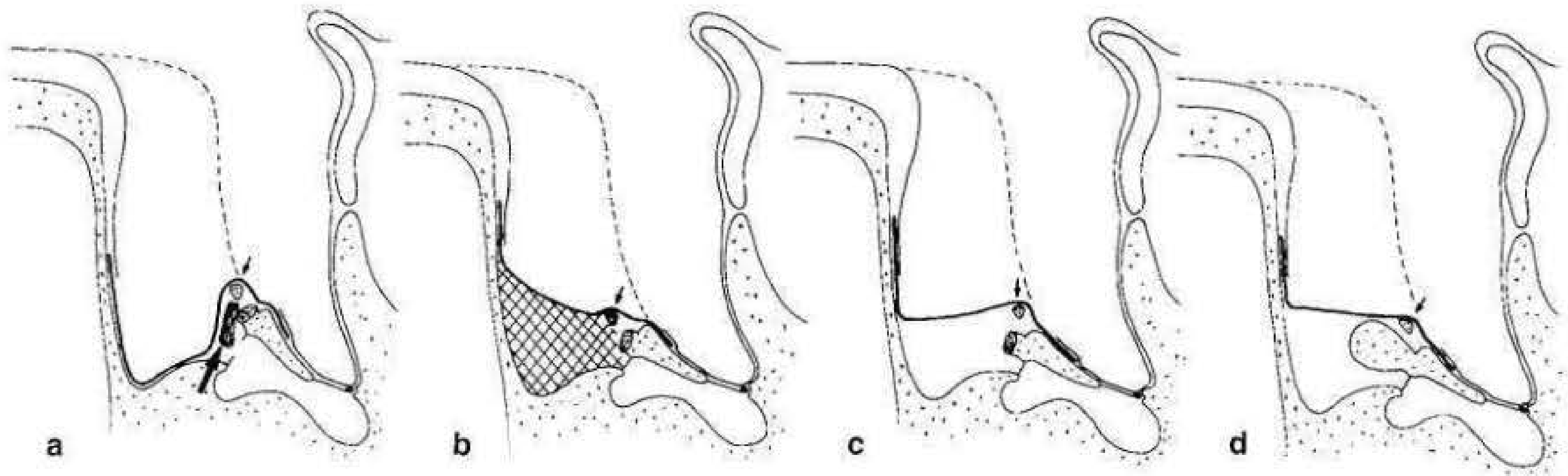


Fig. **728** **Reconstruction of the attic and myringoplasty after canal wall–down mastoidectomy with preservation of the bony bridge.** **a** The attic is open, in Paparella's intact bridge tympanomastoidectomy technique. A thick bridge (small arrow) is covered by fascia, continuing down onto the medial wall of the attic. A piece of muscle is obliterating the connection between the attic and the tympanic cavity (large arrow). **b** The attic is obliterated, and the fascia covers the bridge and the obliterating material. **c** The attic is ventilated in a case without a malleus head. The fascia runs over the bridge onto the tegmen tympani. **d** The attic is ventilated in a case with a preserved malleus head. The fascia runs over the bridge onto the tegmen tympani

(Fig. **728a**). The fascia closes the drum before continuing over the bridge, then it runs down onto the medial wall of the attic, resulting in an open attic (Figs. **715–718**).

An obliterated attic (Fig. **728b**) is seldom the result in cases with a preserved bridge.

Partial obliteration of the attic occurs in cases left with a deep groove after removal of the perilabyrinthine cells (Figs. **686–690**). The attic remains open despite the obliteration.

A ventilated attic is the most common condition in cases with a preserved bridge. In cases with a missing malleus head (Fig. **728c**) the fascia passes from the drum over the bridge to the tegmen tympani (Figs. **706–708**). In cases with a preserved malleus head (Fig. **728d**), the fascia covers the bridge, it is further supported by the head of the malleus, and continues to the tegmen tympani (Fig. **704**). In cases with an intact ossicular chain, in addition to the bridge there is good support for the fascia from the incus and malleus (Figs. **700–702**), and the possibility of ventilation of the attic is high.

The attic can also be ventilated *by partial preservation of the bridge,* e. g., of its posterior part (Figs. **595**, **597**, **713**) or anterior part (Fig. **710**).

In the reconstruction of old radical cavities, or in some canal wall–down mastoidectomies, the attic can be reconstructed using pieces of bone or cartilage to build up its lateral and posterior walls. These methods will be described in Chapter 17.

Relationship Between Attic Reconstruction and the Mastoid Cavity

An *open attic* is usually associated with an open (Fig. **724a**) or a totally or partially obliterated mastoid cavity (Table **11**) (Figs. **722c**, **723c**, **724b**).

In *total obliteration,* a large piece of tragal or conchal cartilage is placed posterior to the lateral semicircular canal (Fig. **729**), representing a new posteriorly displaced ear canal wall, and behind it muscle or other mesenchymal tissue is used to obliterate the cavity. The result is an open attic and an obliterated mastoid cavity — a very common situation.

An example of *partial obliteration* of the cavity (Fig. **730**) is obliteration of the inferior part of the cavity, including the mastoid tip. The attic and antrum are left open, as is the sinodural angle, but the mastoid tip is obliterated, e. g., by placing a cartilage plate into the sinofacial angle inferiorly, and obliterating the mastoid tip with muscle or other materials. Most of the cavity, as well as the attic, remains open. Another example of partial obliteration is the obliteration of a deep sinodural angle. In the classification of obliteration into total or partial, it is the *degree of obliteration* that decides whether a procedure is called an open technique or a closed technique. There is a gradual transition from one to the other.

In an *obliterated attic* (Table **10**), the mastoid cavity can remain as an open cavity (Figs. **690**, **691**, **724d**), or it can be obliterated either totally or partially. The same cavity can be partly obliterated in various regions, e. g., in the attic region, in the sinodural angle or sinofacial angle, as well as in the mastoid tip, and still remain more or less an open cav-

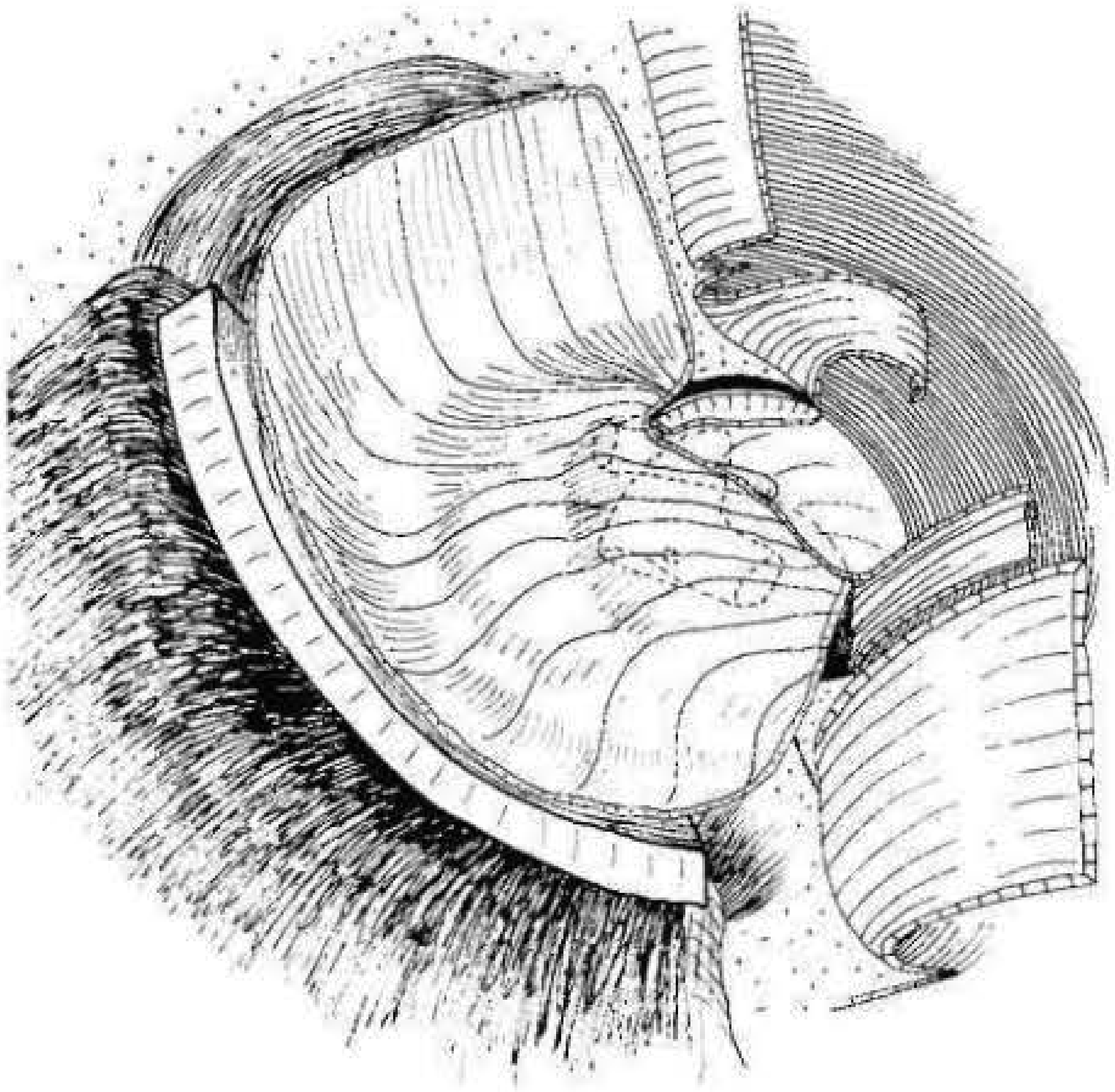


Fig. **729** **Obliteration of the mastoid cavity in a case with an open attic.** The malleus head has been resected and the incus interposed. A piece of fascia covers the drum perforation as an underlay graft, and continues onto the medial attic wall and the mastoid tegmen. A large piece of tragal cartilage is placed posteriorly, forming a new ear canal wall, and behind the cartilage a muscle obliterates the cavity as a pedicled graft

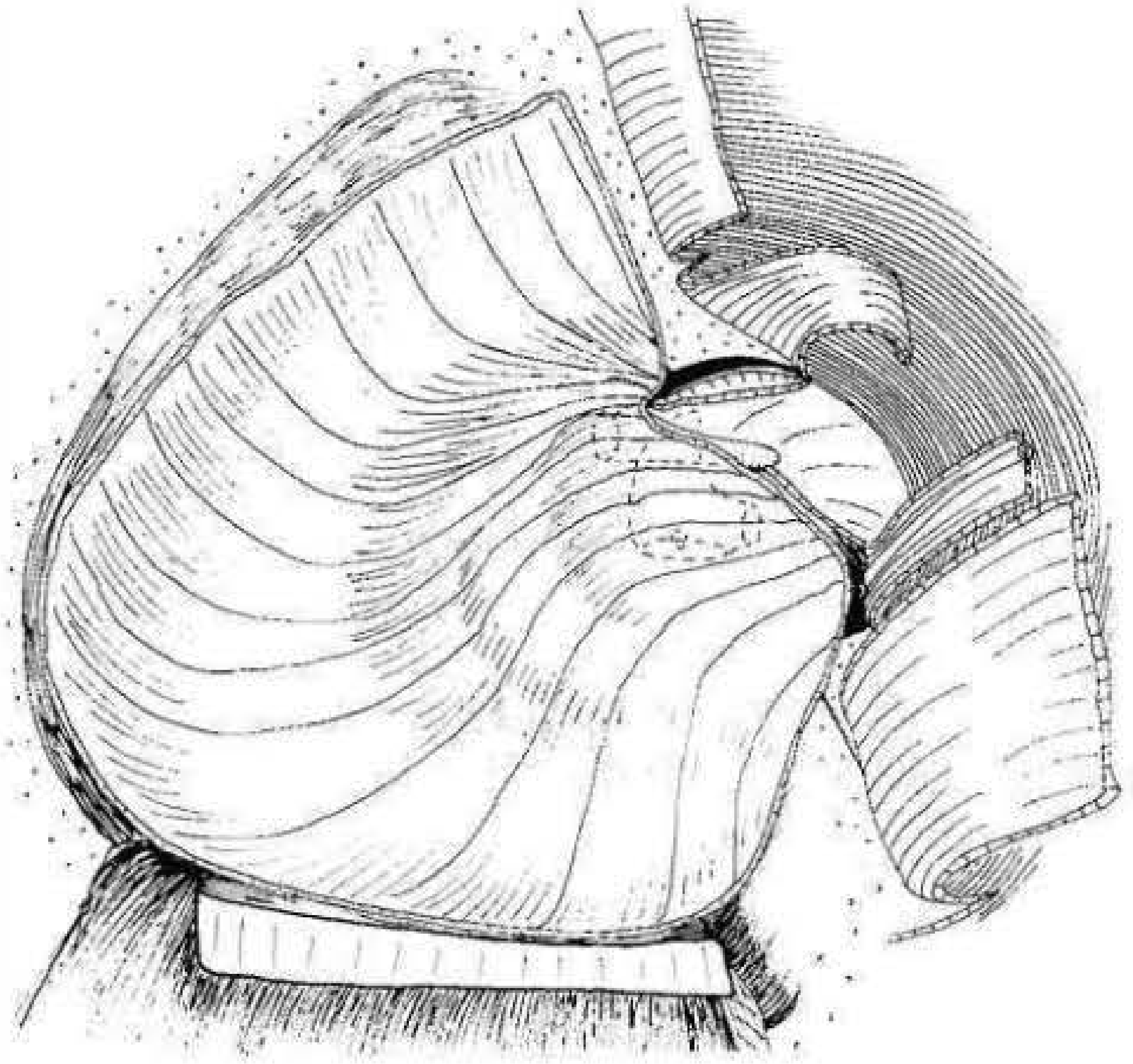
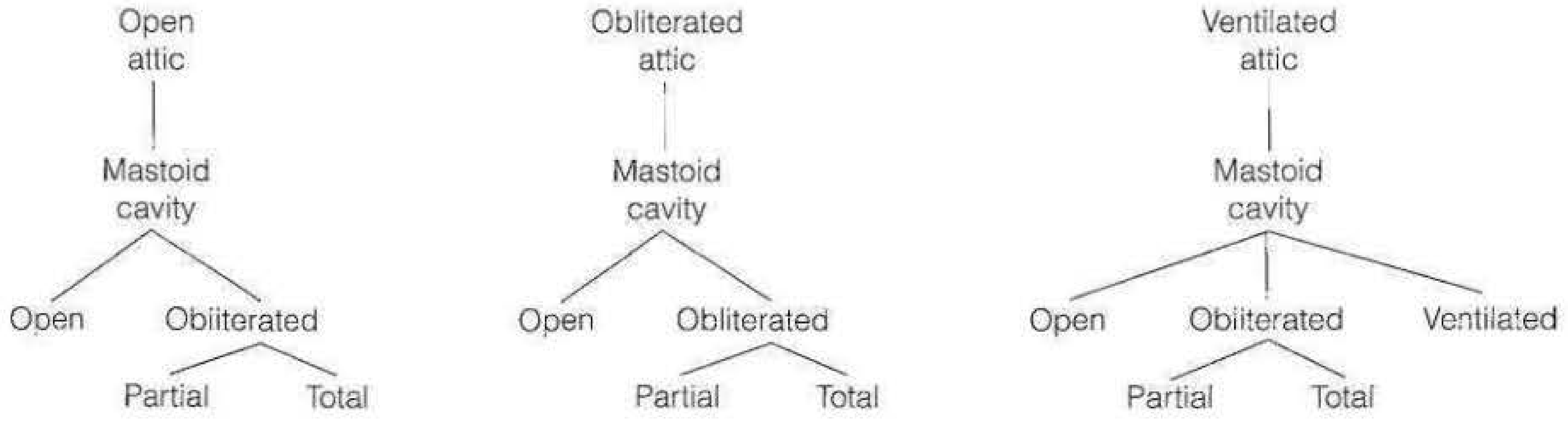


Fig. **730** **Partial obliteration** of the inferior part of the cavity in a case with an open attic and antrum. A piece of fascia, covering the drum perforation, is placed onto the medial wall of the attic and antrum. It turns laterally to cover the mastoid tegmen and the sinodural angle. A cartilage plate is placed inferiorly in the cavity, and behind it a piece of muscle obliterates the mastoid tip

Table **11** Relationship between the reconstruction of the attic and the mastoid cavity


Open attic
Mastoid cavity
Open
Obliterated
Partial
Total
Obliterated attic
Mastoid cavity
Open
Obliterated
Partial
Total
Ventilated attic
Mastoid cavity
Open
Obliterated
Ventilated
Partial
Total

ity with a large meatoplasty. This again illustrates the gradual transition between the terms *partial* and *total* obliteration, and between open and closed techniques.

With a *ventilated attic,* the mastoid cavity can be an open cavity (Fig. **724c**), as in Bondy's operation (Figs. **573**, **557–558**, **644**), or in cases with a preserved bridge and intact ossicular chain (Fig. **700**) or preserved malleus head (Fig. **704**).

The cavity can be obliterated either with preservation (Fig. **720c**) or reconstruction of the ear canal wall (Figs. **721c**, **722b**).

With a ventilated attic, the mastoid cavity is usually ventilated, particularly in intact canal wall mastoidectomy techniques (Fig. **720a**) and in reconstructions of the ear canal wall (Fig. **721b**).

15 The Open Cavity

Despite the many methods of preserving and reconstructing the ear canal wall, as well as the many obliteration methods, an open cavity is still the most common result of mastoid surgery for cholesteatoma. The main reasons for the popularity of open cavity surgery are its simplicity, efficiency, and safety. Canal wall–down mastoidectomy with meatoplasty is the fastest procedure, with few complications; the surgery is nearly always performed in one stage, and the cholesteatoma recurrence rate is low. However, in the long term, too many open cavities discharge and are not selfcleaning. In order to achieve a self-cleaning cavity, several criteria need to be met:

1. Bone work in the canal wall–down mastoidectomy must be adequate and include removal of all mastoid cells and all mucosa, granulation tissue, and other pathology. The cavity, as far as possible, should not be too large. Its walls should be polished without any overhangs or irregularities of the bony plates. The anterior and posterior buttresses should be completely removed and polished. The facial ridge should be low, providing sufficient access to the mastoid tip. These procedures are thoroughly described in Chapters 11–13.
2. The drum perforation has to be closed and the tympanic cavity reconstructed, with or without a bony bridge.
3. The epithelialization of the attic and facial ridge should be guided by a mesenchymal flap or various ear canal skin flaps.
4. The epithelialization of the cavity should be rapid and complete, without formation of granulations. This can be achieved be using either ear canal skin flaps, split-skin grafts, full–thickness skin grafts, or a combination of these. Heterotopic skin is seldom used today; in some situations, it is unavoidable, e. g., in huge cavities, or in ears with no, or very little, ear canal skin available.
5. The meatoplasty should result in a sufficiently wide external auditory meatus, and the laterally based ear canal skin flaps should be pulled posteriorly and sutured close to the posterolateral wall of the cavity to facilitate epithelialization of the cavity from the edges of the ear canal skin flaps.
6. The position of the pinna should not be changed.

Epithelial Covering of the Open Cavity

Cavities have been covered with split–skin grafts, full–thickness pedicled skin grafts, full–thickness free skin grafts, and ear canal skin grafts or flaps. The evolution of the epithelial covering of the cavity reflects the history of the reconstruction methods used in mastoid surgery.

Free Split-Skin and Full-Thickness Skin Grafts

Split–skin grafts. Covering the mastoid cavity with free split–skin grafts (Thirsch grafts), first advocated by Siebemann (1893) in order to cover the bone after radical operations, dominated reconstruction methods before the use of a free full–thickness skin graft become widespread in the 1950s and early 1960s. Split–skin grafts promote rapid healing of the cavity, but experience with the fenestration operation has shown that primary split–skin graft covering of the operative cavity is not desirable. If such a graft took, the epidermal lining of the healed cavity became attached to the bone without an intervening layer of connective tissue (Shambaugh 1959). The surface of the keratinized stratified squamous epithelium was rough and uneven, and it continued to desquamate excessively. In localized areas, breakdown of the epithelium occurred, and the epithelium was replaced by granulation tissue with discharge, requiring later revision. Many surgeons, after performing radical operations with removal of the matrix, therefore abandoned primary covering of the cavity with Tirsch grafts, since the cavity would slowly heal without an epithelial covering. However, such healing could take quite a long time. If the surgeon wishes to shorten the period of final healing, a split–skin graft can be applied to the cavity two or three weeks postoperatively, after the cavity has become lined by a thin layer of healthy granulations, which then provide the required subepithelial connective tissue layer. Paparella has systematically used split–skin grafting of the cavity in a second–stage procedure three weeks after the intact bridge mastoidectomy technique, and reported good results (Paparella and Jung 1983, 1984, Goycoolea et al. 1989).

Harvesting of split–skin grafts is described in Volume 1, pp. 125–6. Usually, the thinnest possible split–skin graft, with a thickness of 0.1–0.05 mm, is used.

Full–thickness skin grafts. Autogenous heterotopic full–thickness skin grafting was introduced into modern otosurgery by Wullstein and Zöllner in the early 1950s, but the disadvantages of a full–thickness free skin graft soon became obvious. Many of the cavities continued to discharge, and granulation tissue and eczema–like condition developed within the cavity. Whilst free full–thickness postauricular skin grafts behaved well in the tympanum, behavior in the mastoid segment could not be predicted. Often, a satisfactory primary take of the skin graft was observed, but partial and delayed breakdown was common. When this occurred, one was left with a granulating area in the mastoid segment that was difficult to treat, and in several cases profuse discharge persisted and resisted therapy (Beales 1959).

Pedicled Skin Grafts

To obtain a good, resistant skin lining within a radical cavity, pedicled full–thickness skin grafts were used sporadically as early as the early part of this century. The Preysing double *full–thickness pedicled skin grafts* (Preysing 1910) are created using two parallel retroauricular skin incisions (Fig. **731**). The two skin pedicles are liberated, the subcutaneous tissue is removed, and the pedicles are then inserted into a canal wall–down mastoidectomy cavity (Fig. **732**). After replacement of the ear canal skin flaps and the Körner flap, the widened ear canal and the cavity are packed, thus fixing the pedicled skin flaps. Only the middle part of the wound is sutured (Fig. **733**). Fourteen days after the initial surgery, the base of the flaps is cut, and secondary suturing of the wound is carried out.

This basic method was modified during the 1950s, with usually only one pedicled skin flap being used, either based superiorly (Fig. **734**) (Vincencio 1956, Gundersen 1961), inferiorly (Fig. **735**) (Charland 1960, Bourdial et al, 1961), or pedicled posteriorly (Beales and Hynes 1958, Grahne 1963).

A common feature of all the pedicled skin grafts is that the edge of the cavity wall, either superiorly or inferiorly, should be drilled off and rounded, to avoid pressure and hence disturbance of the blood supply to the flap.

Pedicled Skin–Subcutis Skin Grafts

For primary closure of the retroauricular wound, Mayer (1917) used a modification (Fig. **736**). An ellipse incision is performed passing through the skin, subcutis, and periosteum, except in the middle, where only the skin is incised and a 1–cm piece of skin is removed, exposing the sbucutis (Fig. **736**). After a canal wall–down mastoidectomy, the inferior periosteum–subcutis, full–thickness skin graft is elevated and placed in the inferior part of the cavity. The superior graft covers the superior part of the cavity. Both flaps remain attached to the pedicle of subcutis–periosteum tissue, which is freed from the skin (Fig. **737**). The flaps are supplied through this subcutis–periosteal pedicle, and epithelialization proceeds quickly, resulting in a smaller cavity,

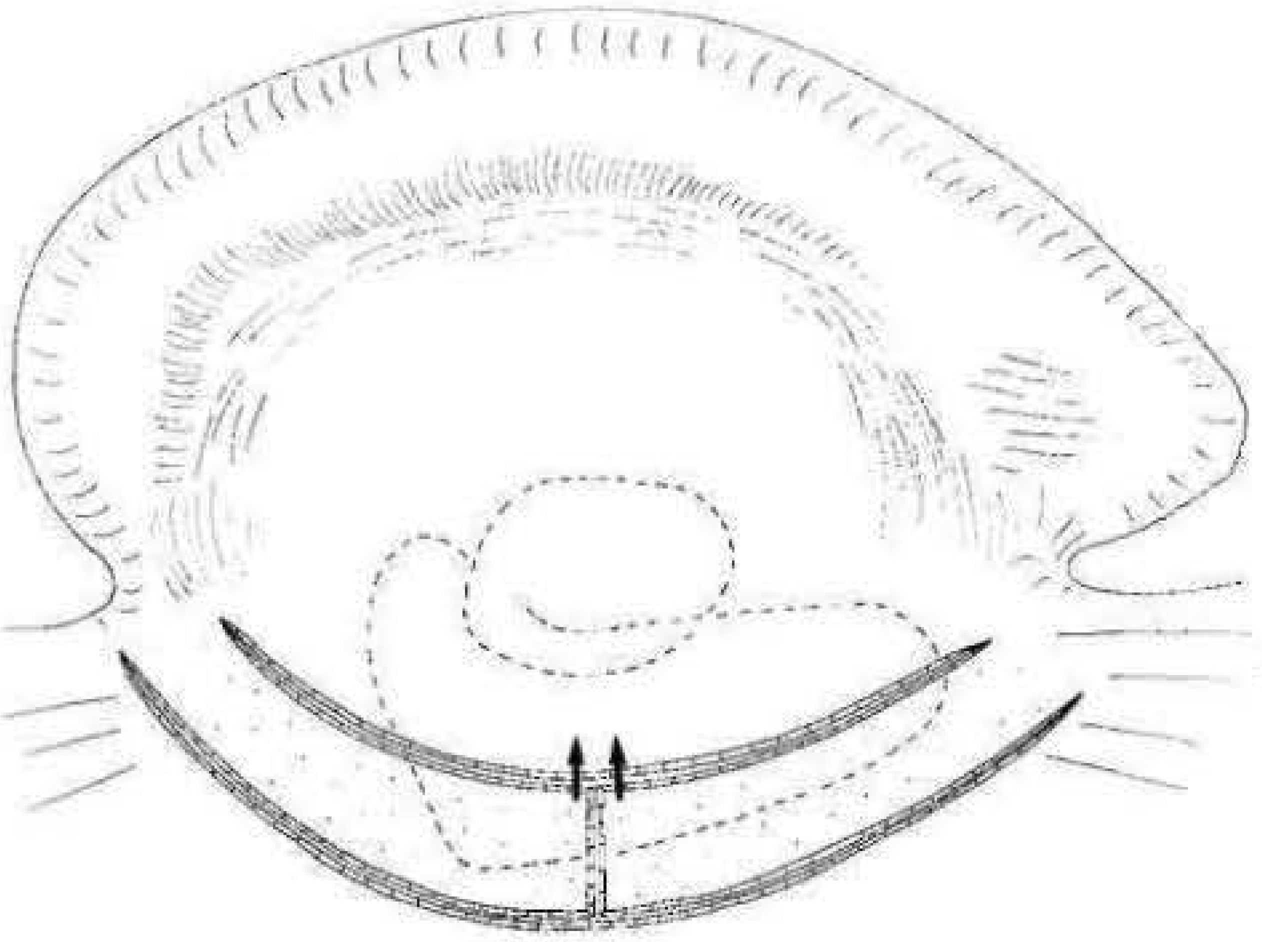


Fig. **731** **The two Preysing full-thickness skin grafts.** After two parallel retroauricular incisions, the skin pedicles are liberated and cleaned of subcutaneous tissue. The dashed lines indicate the position of the mastoid cavity and the tympanic cavity

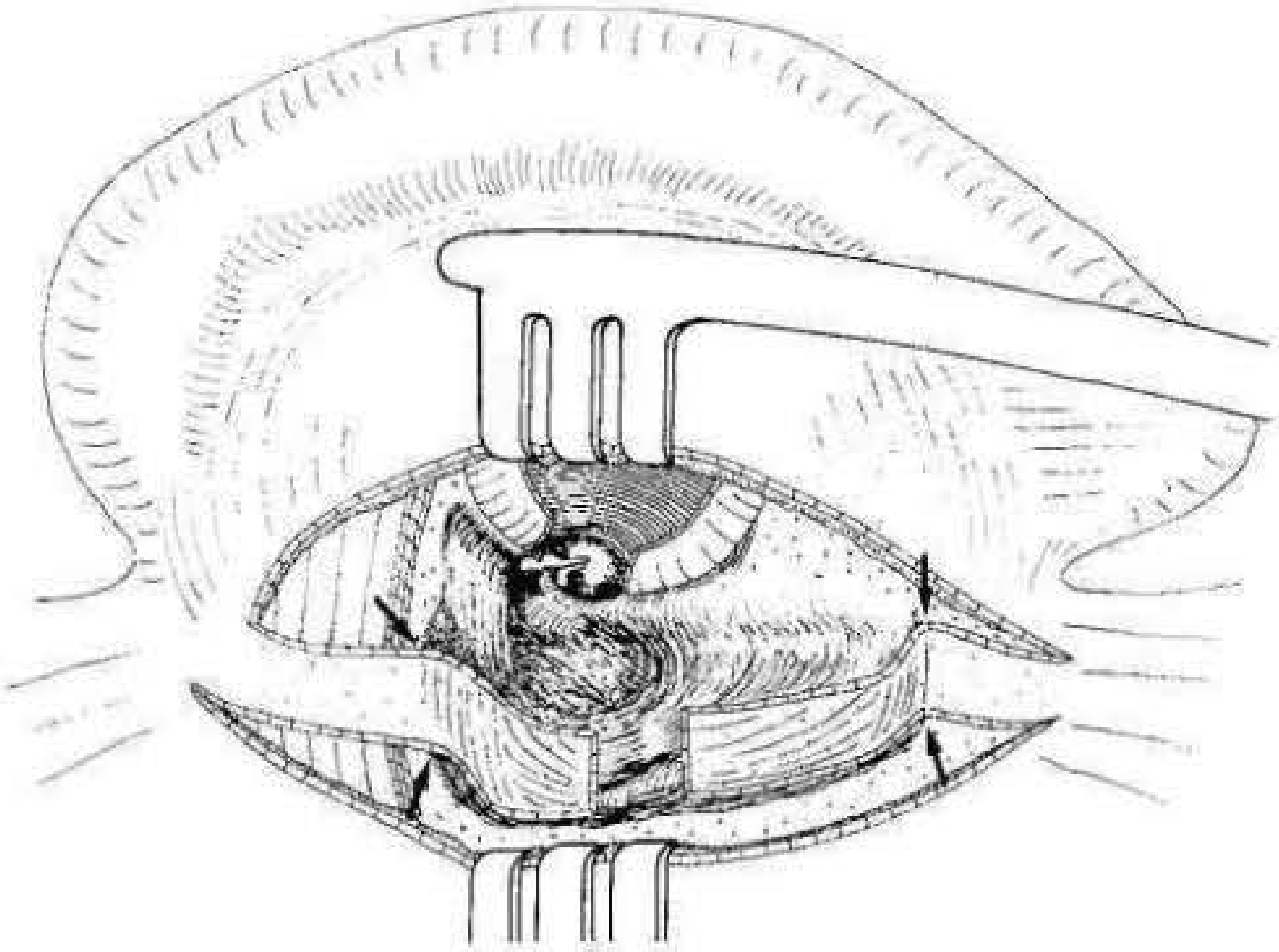


Fig. **732** The canal wall–down mastoidectomy cavity covered with two pedicled skin flaps. The edges of the cavity are rounded (arrows) to avoid disturbance to blood circulation in the flaps

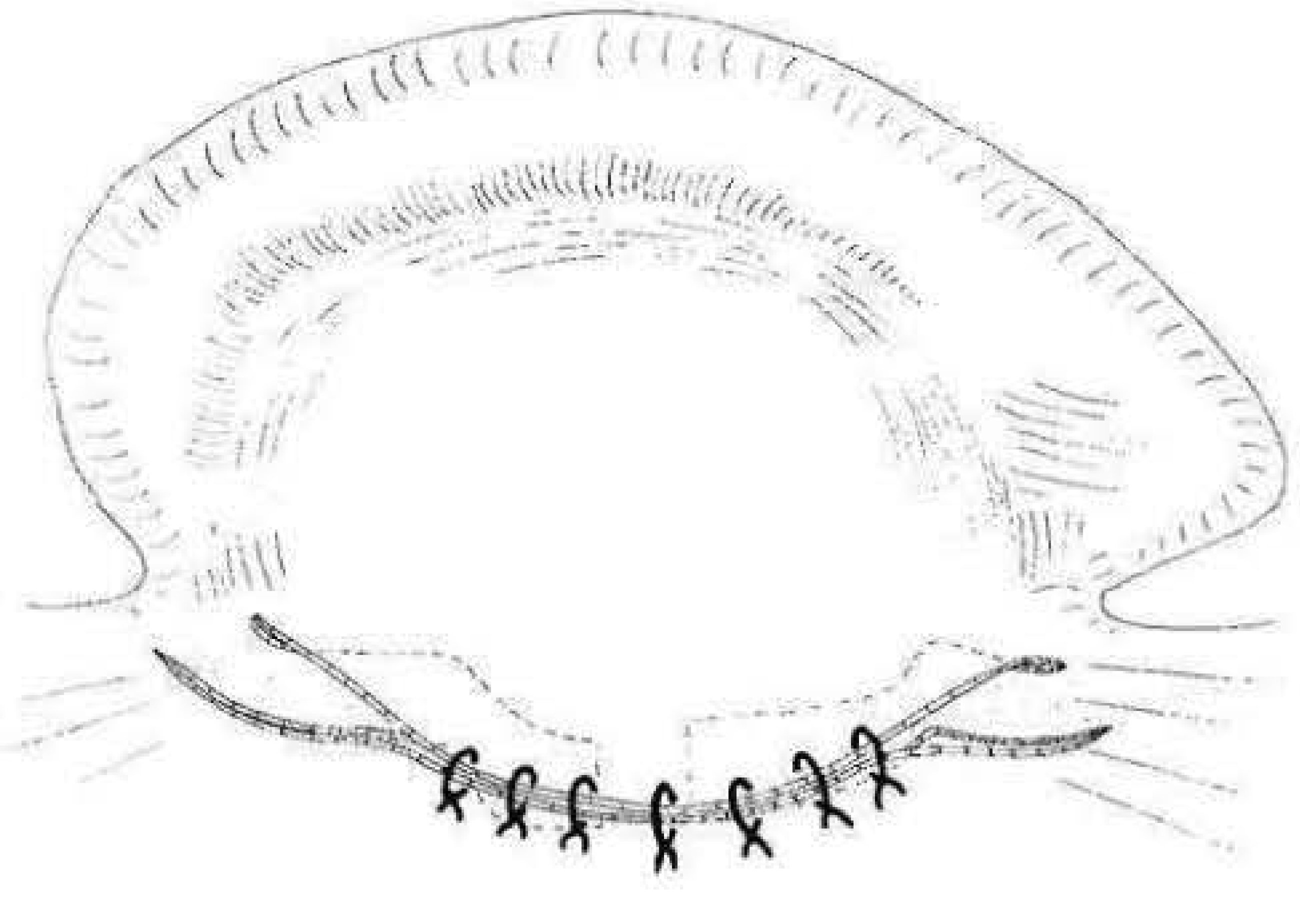


Fig. **733** The postauricular incision is closed, except inferiorly and superiorly. The bases of the flaps will be cut 14 days later, and the wounds sutured secondarily at the same time

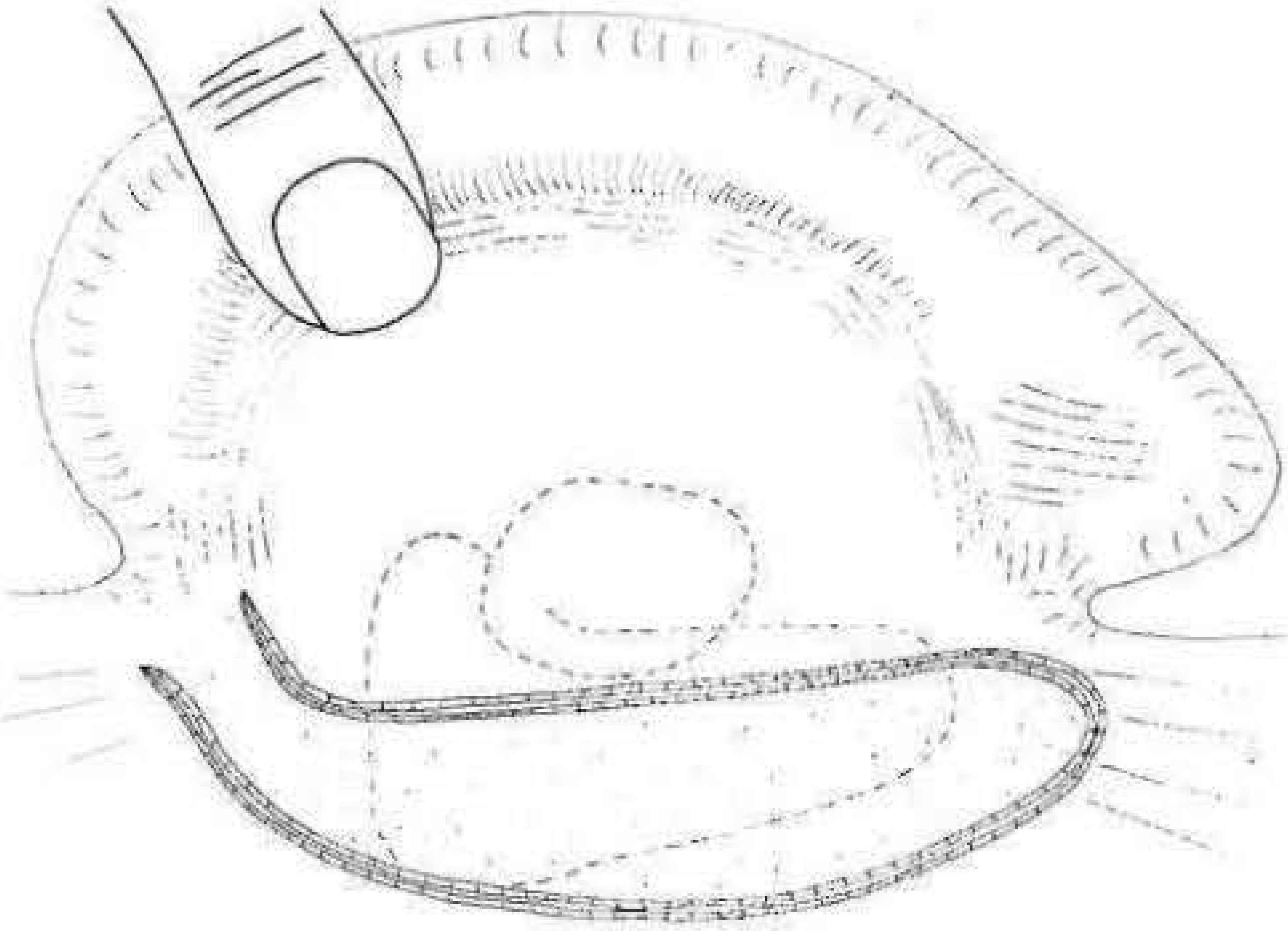


Fig. **734** Incision for a superiorly-based skin flap

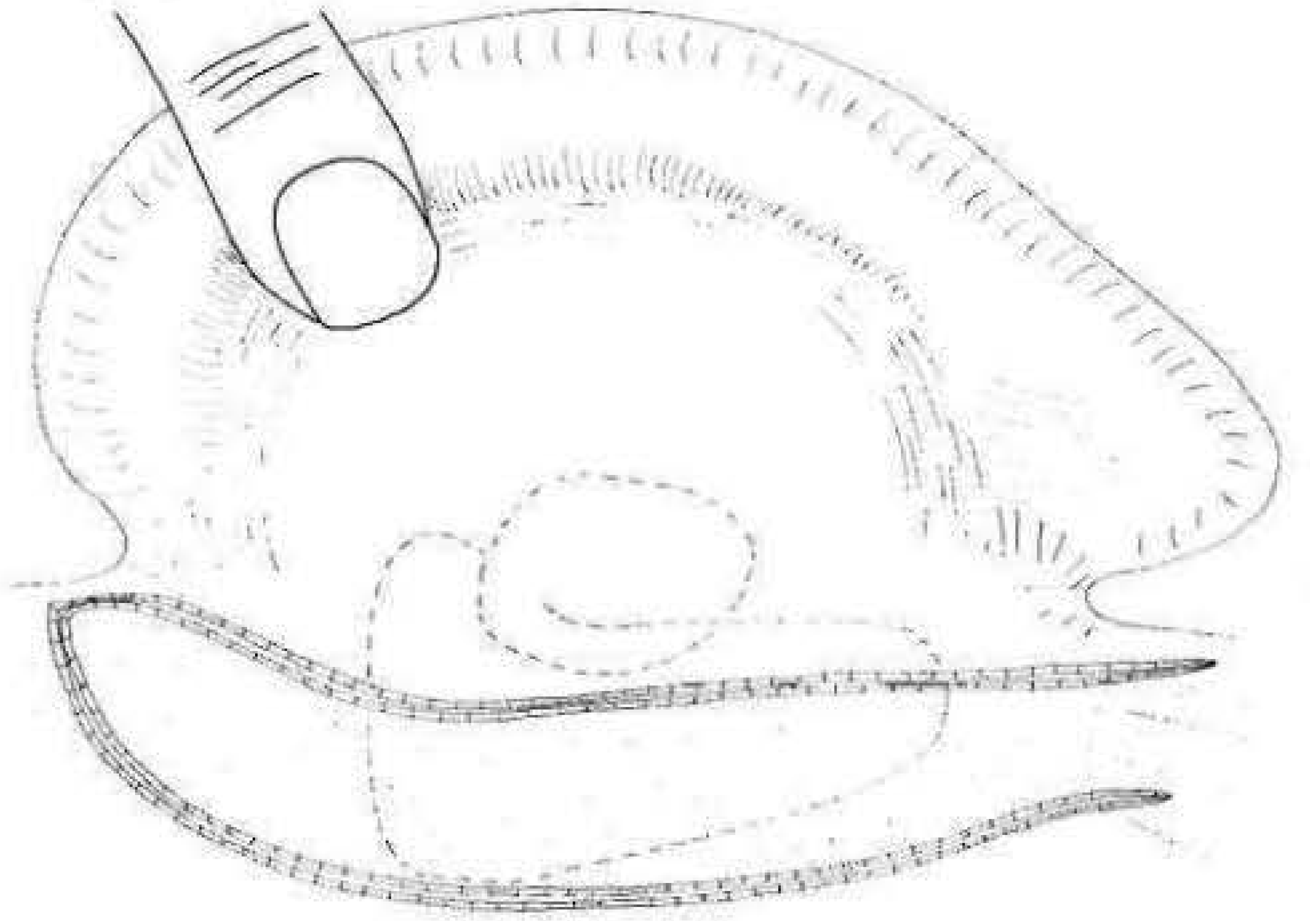


Fig. **735** Incision for an inferiorly-based skin flap

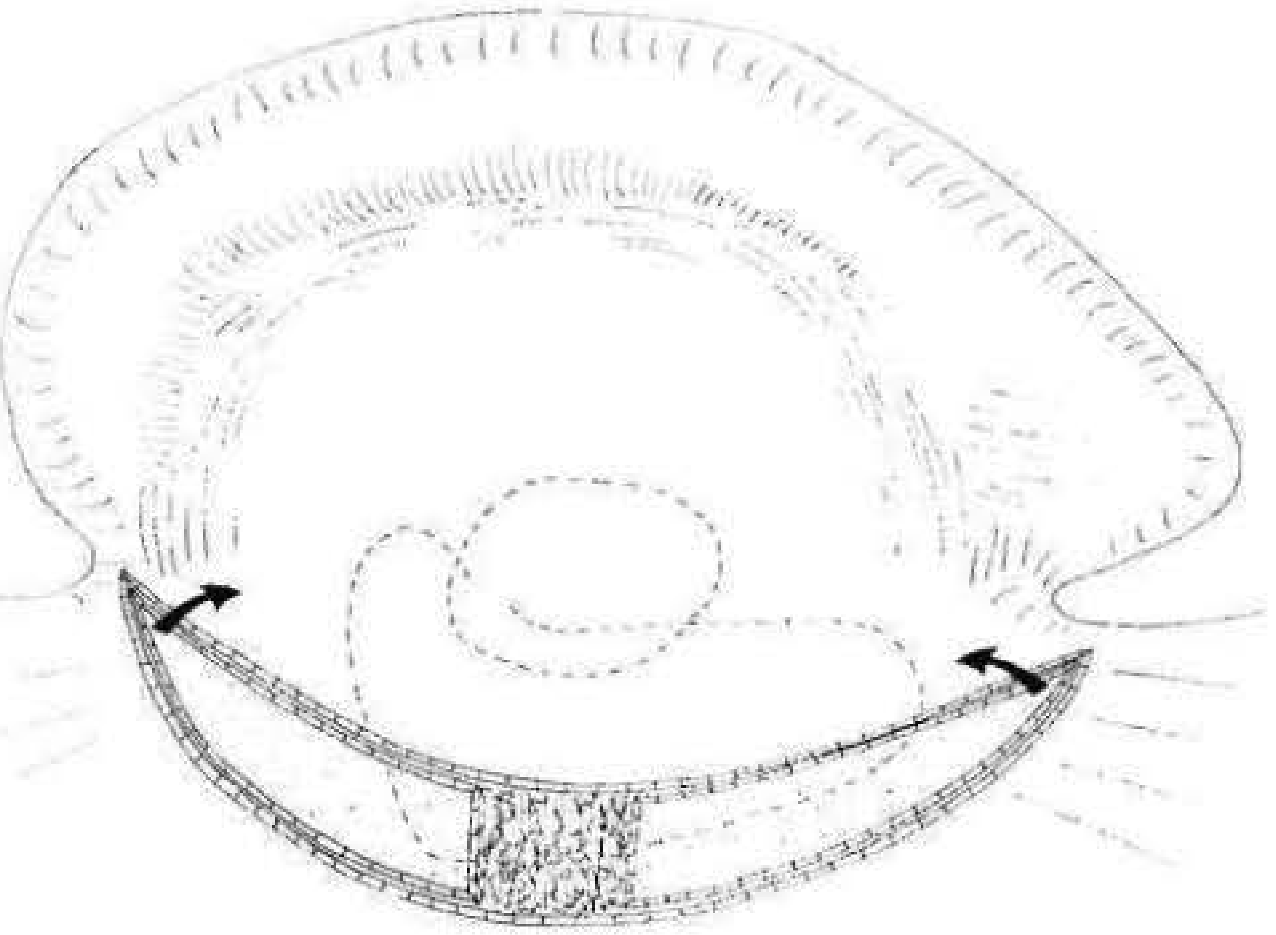


Fig. **736** **The original Mayer skin–subcutis pedicled grafts.** Two parallel skin incisions are made, going through the skin, subcutaneous tissue, and periosteum. In the central part of the flap, skin is removed. The flaps will be inserted with their conical ends (arrows) into the cavity

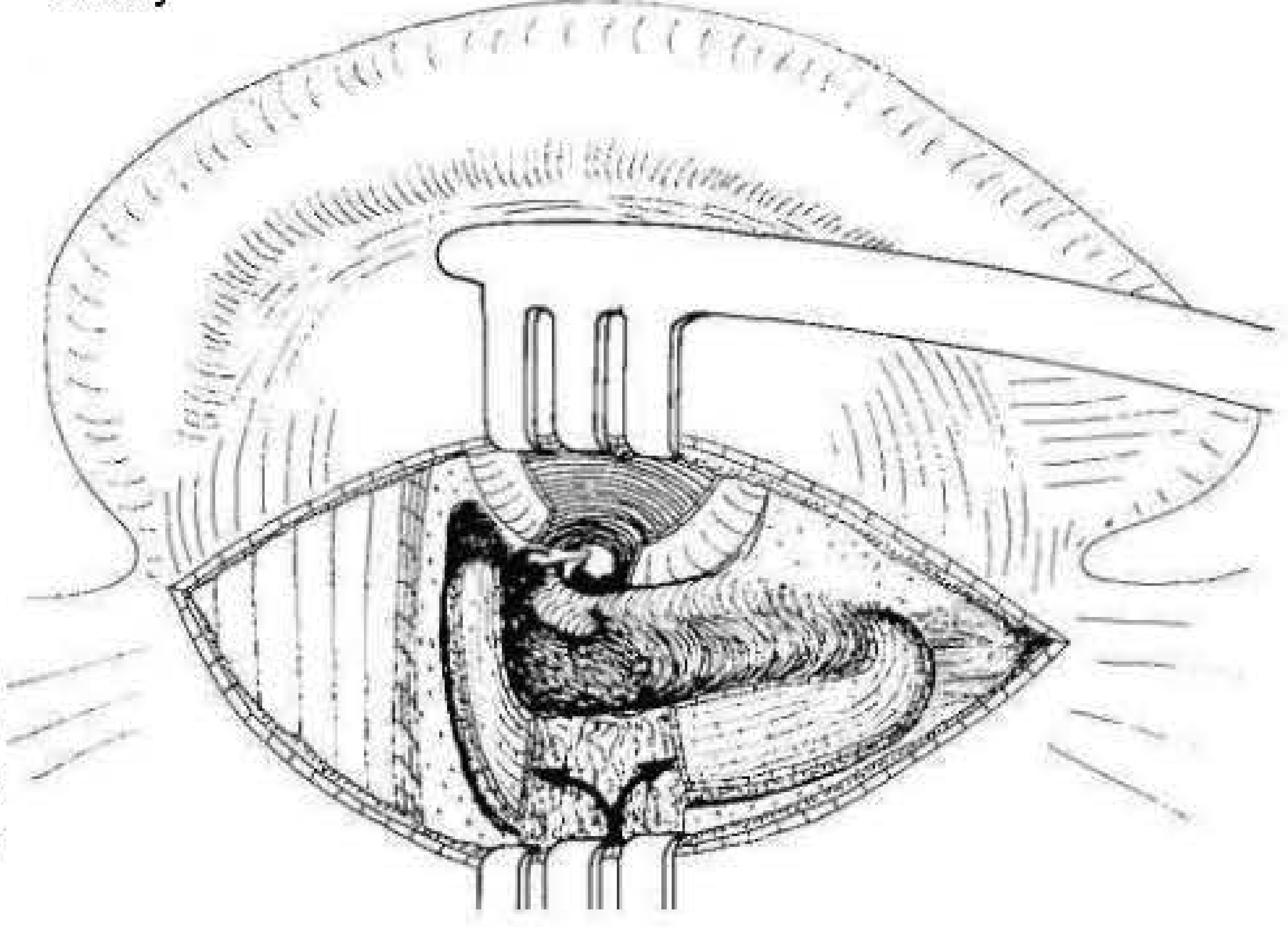


Fig. **737** The skin–subcutis flaps are in position in the cavity. One is covering the superior wall, and the other the posteroinferior wall. The vascular supply to the flaps comes through the pedicled subcutaneous tissue (arrows)

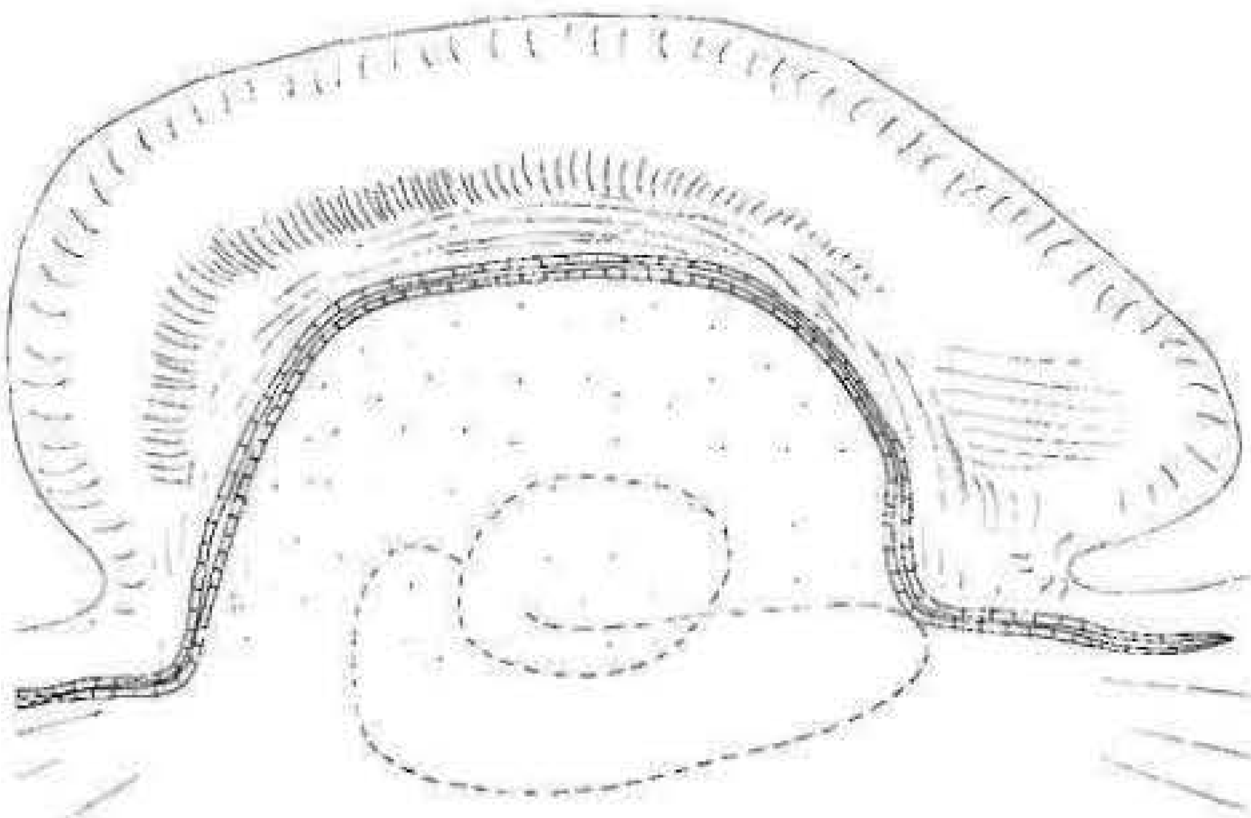


Fig. **738** **The Beales and Hynes posteriorly bases skin–subcutis flap.** The incision goes through the skin and the subcutaneous tissue down to the perichondrium

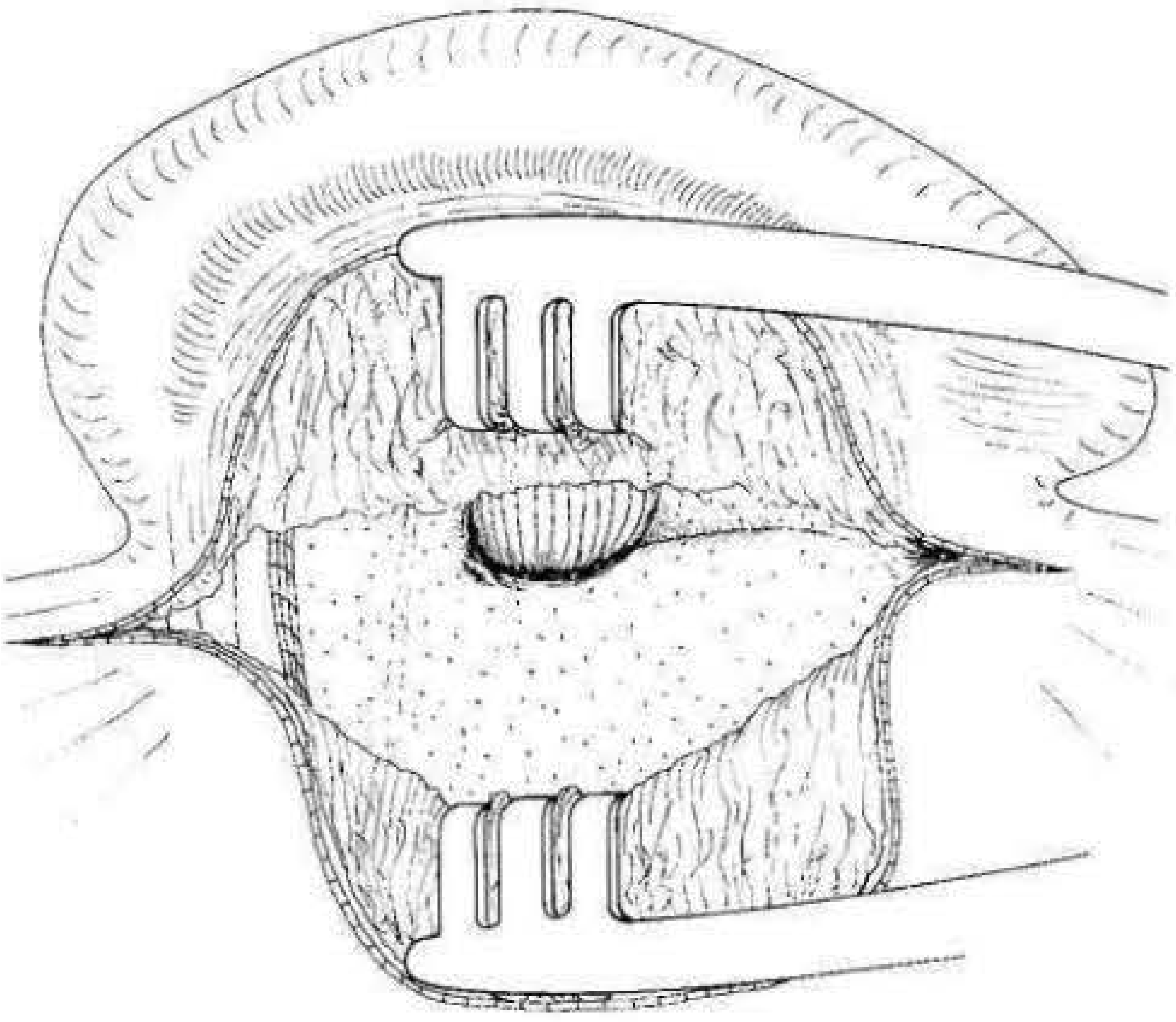
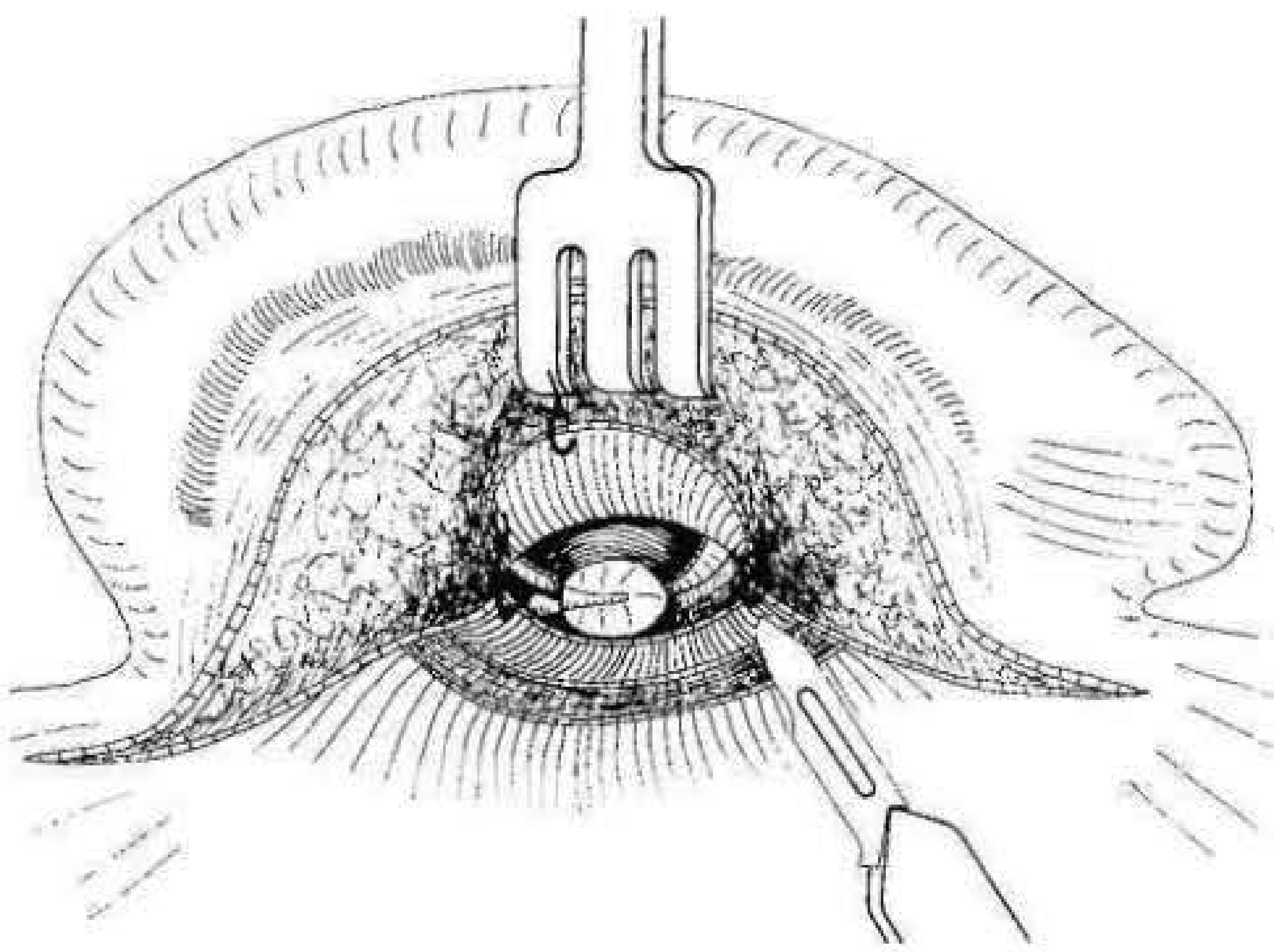


Fig. **739** The subcutis–skin flap is elevated, exposing the cortical bone of the mastoid plane. The ear canal skin is not opened



because the flap also consists of retroauricular subcutaneous and fibrous tissue. The wound is closed primarily, which is a great advantage.

Beales and Hynes (1958) published an interesting method using a large, posteriorly-based skin–subcutis flap. After a skin incision on the posterior aspect of the pinna, passing through the subcutis to the surface of the perichondrium (Fig. **738**), the flap is elevated and turned backward, exposing the mastoid bone (Fig. **739**). After a canal wall–down mastoidectomy, a small Körner flap is created and sutured to the posterior aspect of the ear canal and the pinna. Superiorly and inferiorly, the skin–subcutis flap is sutured to the Körner flap, holding the Körner flap in position (Fig. **740**). A thin layer of the epithelium is scraped off the pedicle of the postauricular flap with a knife. This shaved surface is about 0.5 cm wide, and is sutured to the subcutaneous tissue of the concha. These sutures hold the ear canal wide, and keep the Körner flap attached to the posterior border of the cavity. Finally, the posterior surface of the pinna is covered with a large split–skin graft, sutured to the skin edges (Fig. **741**). Beales (1959) reported the one–year results in 44 patients using this method. Eighty-four percent of the ears remained dry, with healed cavities, and only

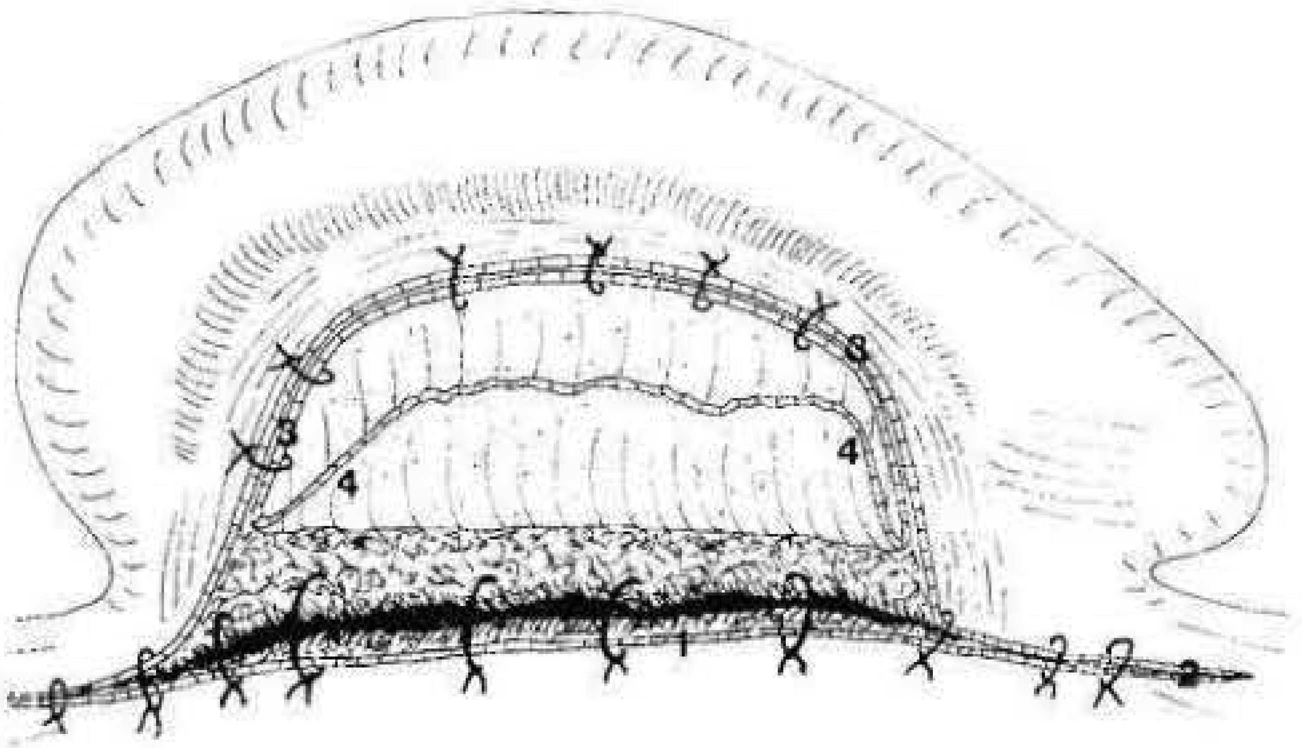


Fig. **741** The Körner flap, together with the tissue covering the mastoid process, is sutured to the base of the subcutis–skin flap at the region of removal of the epithelium (1). The superior and inferior parts of the skin are sutured (2), the large skin defect of the pinna is covered with a large split-skin graft sutured to the edges of the wound (3), and finally the split–skin graft is adapted to the edge of the skin in the postauricular fold (4)

◁ Fig. **740** After a canal wall–down mastoidectomy, the posteriorly-based subcutis–skin flap is pressed into the cavity. It is sutured to the inferiorly and superiorly-based ear canal skin flaps. A Körner flap from the posterior wall of the ear canal is sutured to the posterior aspect of the ear canal and the pinna. Posteriorly, a 0.5-cm wide strip of skin is excised or scraped using a scalpel, allowing primary suturing of the wound five percent of the cavities had small unhealed areas requiring occasional outpatient treatment.

Some of the pedicled skin–subcutis grafts have also been used to obliterate the cavity. Grahne's superiorly-based epithelial–subcutis flap (1963), using a similar incision as the Vincencio and Gundersen flaps (Fig. **734**), includes all the postauricular subcutaneous tissue and the temporalis muscle. Distally, the flap even includes fibers of the sternocleidomastoid muscle, and if necessary this flap can be made relatively thick. After an endaural canal wall–down mastoidectomy (Fig. **742**), the pre-prepared flap is pulled into the cavity, covering and obliterating the upper part of the cavity. The lower part is covered with a inferiorly-pedicled meatal skin flap. The postauricular skin is closed primarily, except at the very top part. The vital pedicle is cut one month after primary surgery, and the upper part of the incision is then closed.

Most methods are based on secondary cutting of the flap after it has healed onto the cavity wall. Some surgeons cut the skin base one month, some two or three months after primary surgery (Charland 1960). In the Beales and Hynes method, a strip of skin is cut at primary surgery, and the incision is closed primarily.

Richtner (1960) used a double inferior pedicled flap (Fig. **743**). The anterior flap is a skin flap to cover the tympanic cavity and attic. The posterior flap is a periosteum–muscle–skin flap, covering the inferior part of the cavity behind the facial ridge (Fig. **744**).

In the conservative radical operation preserving the bridge, the skin flap covers the facial ridge, the attic, and the tympanic cavity, creating a myringostapediopexy or type 4 tympanoplasty. The muscle flap covers the antrum and the mastoid tip (Fig. **745**). The posterior incision is closed primarily.

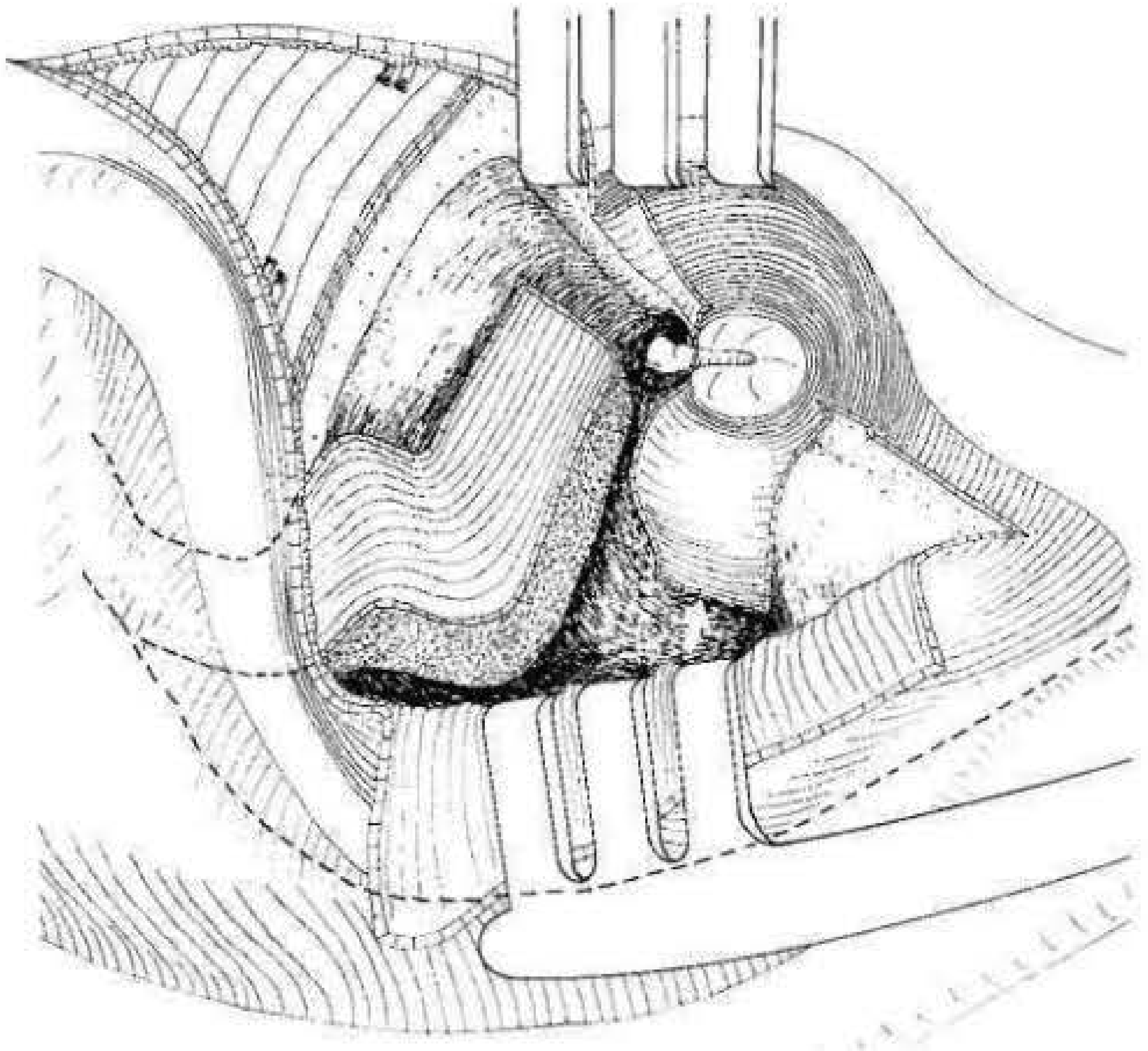


Fig. **742** **The Grahne pedicled full-skin subcutis–muscle flap** after two postauricular incisions. The flap is elaborated using a postauricular incision. It consists of skin, subcutis, and muscle fibers up to the periosteum. After an endaural canal wall–down mastoidectomy, the flap is pulled into the cavity, covering its superior part. Inferiorly, a large ear canal skin flap is covering the cavity and the facial ridge (arrow)

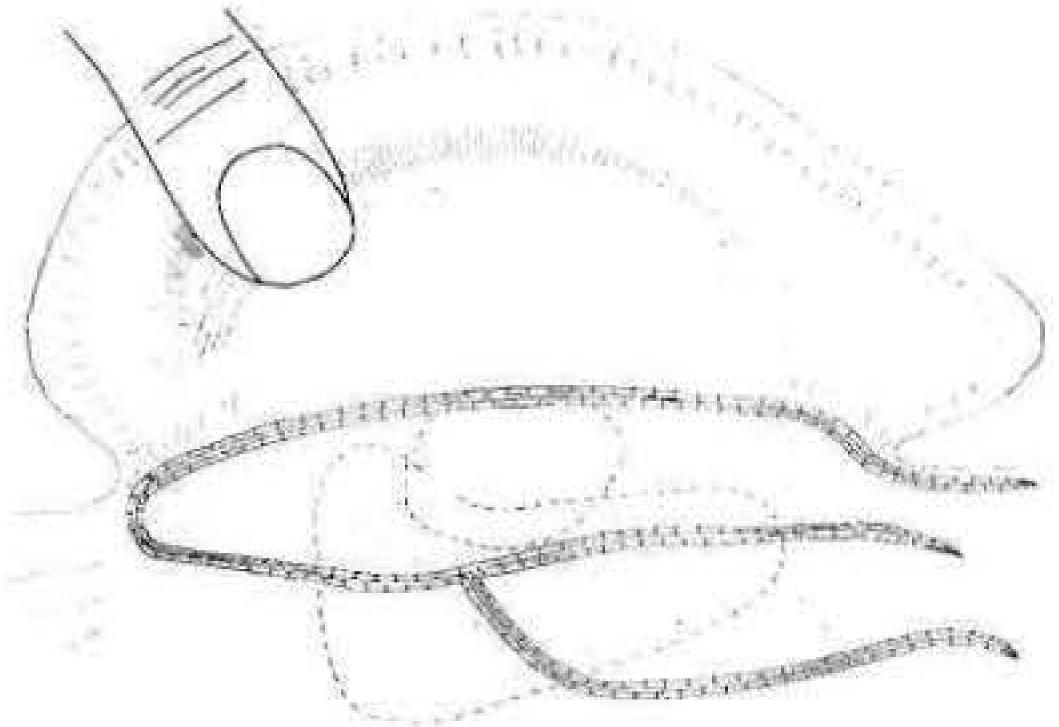


Fig. **743** **The Richtner double inferiorly-based flaps.** The incisions for the two flaps are made through the skin and subcutaneous tissue

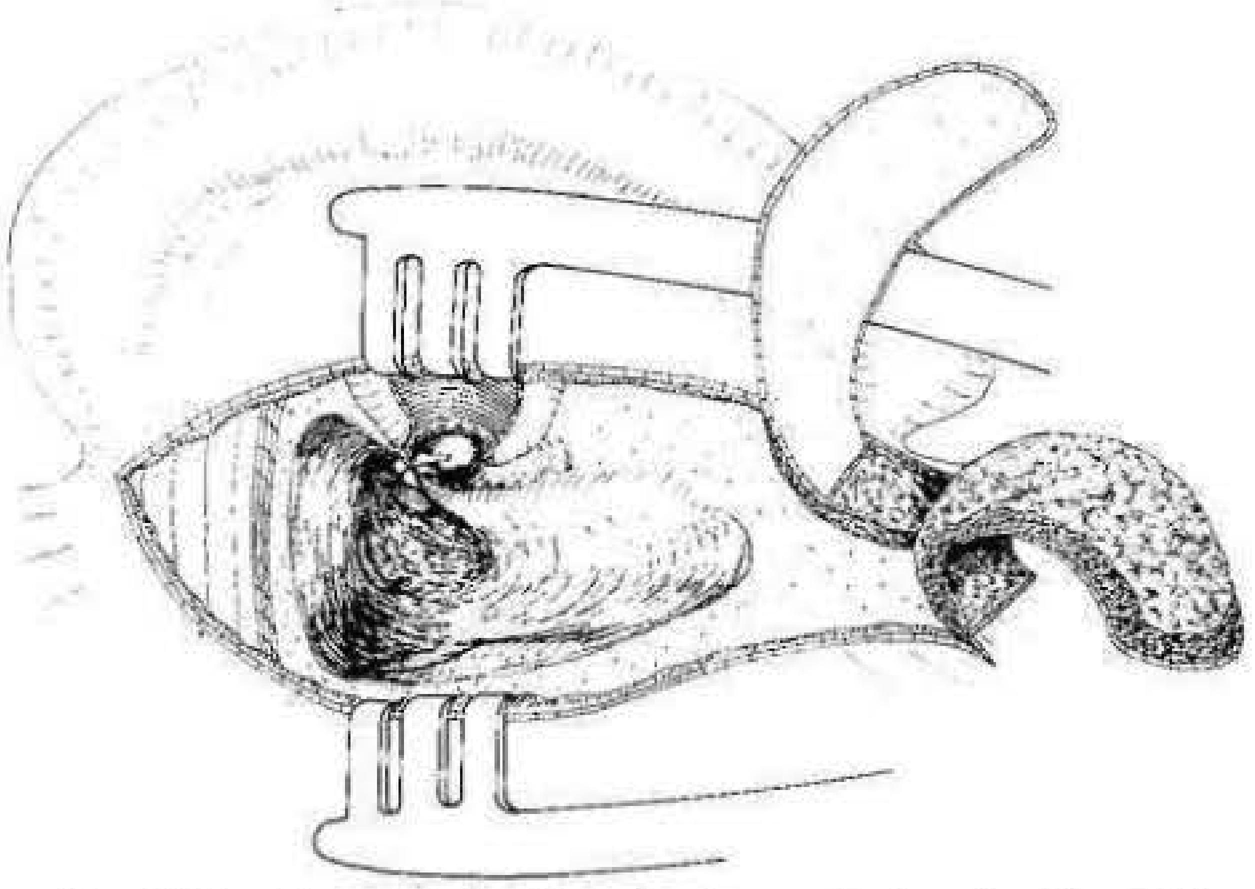


Fig. **744** The anterior flap is cleaned of subcutis. At the base of the flaps, the skin is removed

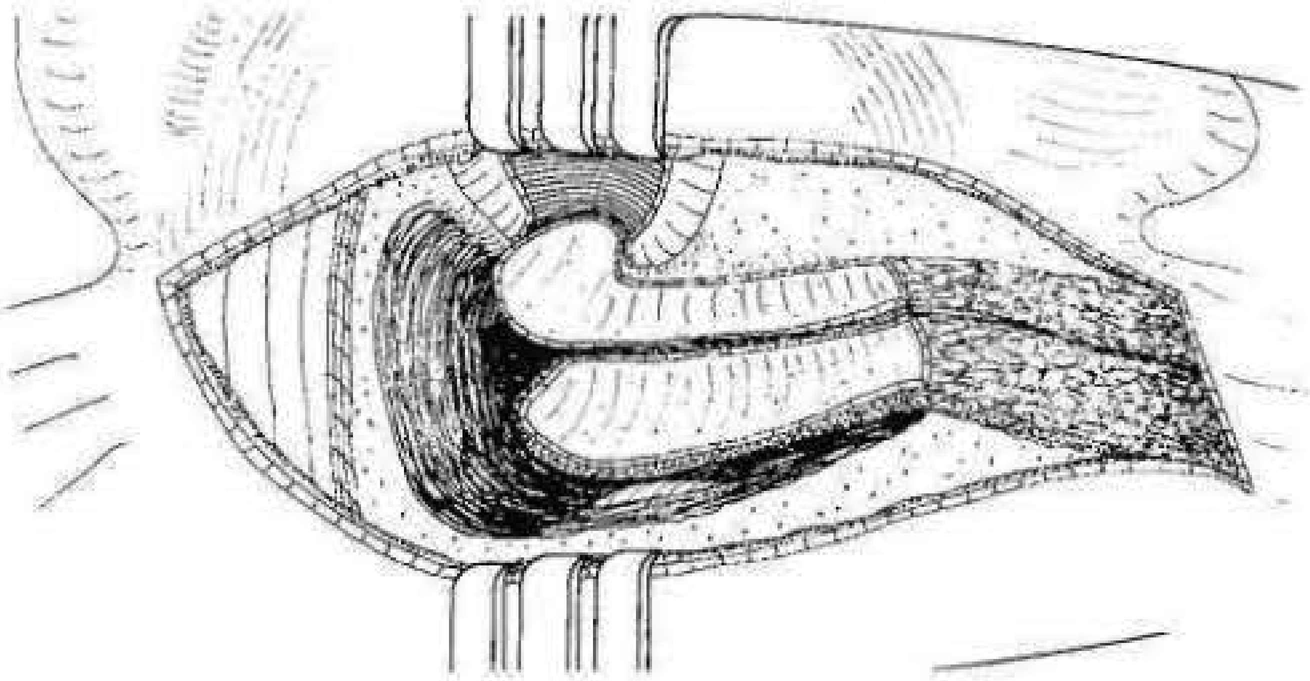


Fig. **745** The skin flap is placed on the drum perforation and on the facial ridge. The posteriorly-positioned skin–subcutis flap is obliterating and covering the inferior part of the cavity. The wound is closed primarily

Pedicled Ear Canal Skin Flaps

The ear canal skin flaps are the most important factors in the healing and epithelialization of an open cavity. Creation of ear canal skin flap has sometimes already occurred during the approach to the ear canal and tympanic cavity. During the approach, the ear surgeon should already have an idea of how to reconstruct the ear canal wall if the mastoidectomy should end up as a canal wall–down mastoidectomy, and flaps are the cornerstone of this reconstruction. In Volume 1, the many types of ear canal skin flap are illustrated for the endaural and retroauricular approaches in myringoplasty and tympanoplasty. Here, only the supplementary surgery of the flaps in relation to a canal wall–down mastoidectomy will be indicated.

Generally, there are three main types of ear canal skin flap. These are:

1. The laterally-based Körner flap (Fig. **659**).
2. The medially-based Surdille flap (Figs. **660–662**).
3. The inferiorly-based Stacke flap or Panse flap.

The level and location of the various ear canal skin incisions determines the size of the flap.

The Körner Flap

The Körner flap is based laterally, and provides the covering and the source of epithelialization for the posterior aspect of the cavity.

The *Körner flap in an endaural approach.* In the Heermann B modification of the endaural approach (Fig. **659**) the radial incisions are placed at the 12-o'clock and 6-o'clock positions, and a circumferential incision connects the two radial incisions, dividing the posterior ear canal skin into a medial and a lateral flap (Fig. **746**). The elevated lateral flap of ear canal skin is the distal part of the Körner flap, which can be extended during the meatoplasty. The medially-based tympanomeatal flap can be of varied size, again depending on the position of the circumferential incision. If the incision is placed laterally, as in Shambaugh's and Lempert's modifications, the Körner flap is small but the tympanomeatal flap is large, and in such cases it is called the Surdille flap (Figs. **660, 661**).

In the Heermann B incision, the superior ear canal skin flap is small, but it can be enlarged by a separate skin incision placed anteriorly in the ear canal at the 3-o'clock position. This flap is based medially, and can cover the superior wall of the cavity (Fig. **746**). Medially, the tympanomeatal flap covers the medial wall of the posterior attic, aditus and antrum and antrum, and part of the facial ridge.

For reconstruction in a canal wall–down mastoidectomy, the Körner flap is created at the end of the procedure, during the meatoplasty. Two radial incisions of about 1 cm each are made through the conchal skin and cartilage from the edge of the ear canal towards the cavum conchae (Fig. **746**). The Körner flap is elevated laterally from the conchal cartilage using a pair of scissors, exposing a 0.5 to 1.0 cm–wide strip of the medial part of the conchal cartilage, which is then excised, enlarging the ear canal and elongating the Körner flap (Fig. **747**).

The Körner flap is pushed posteriorly into the cavity, covering the posterior aspect of the cavity (Fig. **748**). In an endaural approach, it is held in place by a strip of gauze moistened with hydrocortisone and Terramycin ointment. Superiorly, the anterosuperior flap covers the attic and tegmen tympani, and inferiorly, the tympanomeatal flap covers the aditus ad antrum (Figs. **748, 749**).

The Körner flap in a retroauricular approach. To achieve a long and rectangular Körner flap in a retroauricular approach, the Wullstein–Kley technique is used, with radial incisions at the 12-o'clock and 6-o'clock positions and a relatively medially placed circumferential incision (Vol. 1, Figs. **96–105, 108–110**). The flap is elevated and held in place during canal wall–down mastoidectomy by a self-retaining retractor (Fig. **615**). After completion of the canal wall–down mastoidectomy, the meatoplasty is performed, elongating the radial incisions at the 6-o'clock and 12-o'clock positions up to the conchal cartilage (Fig. **750**). The selfretaining retractor is then repositioned, the fibrous tissue from the posterior aspect of the conchal cartilage removed, and the cartilage exposed. Using a knife, a 1-cm–broad strip of cartilage is excised and separated from the perichondrium using a rugine (Fig. **751**). The Körner flap is thus elongated, and the ear canal widened. Along with the auricle, the Körner flap is then pulled posteriorly and sutured to the subcutaneous tissue at the posterior edge of the cavity. The flap is carefully adapted to the posterior wall of the cavity (Fig. **752**). Medially, the meatal skin flaps are replaced posteriorly over the fascia, partly covering the facial nerve, the lateral semicircular canal, and the medial wall of the attic, as well as the tegmen tympani superiorly. The cavity is filled with Gelfoam and moistened with antibiotic, and a strip of gauze moistened with hydrocortisone and Terramycin ointment, is left in place for three weeks.

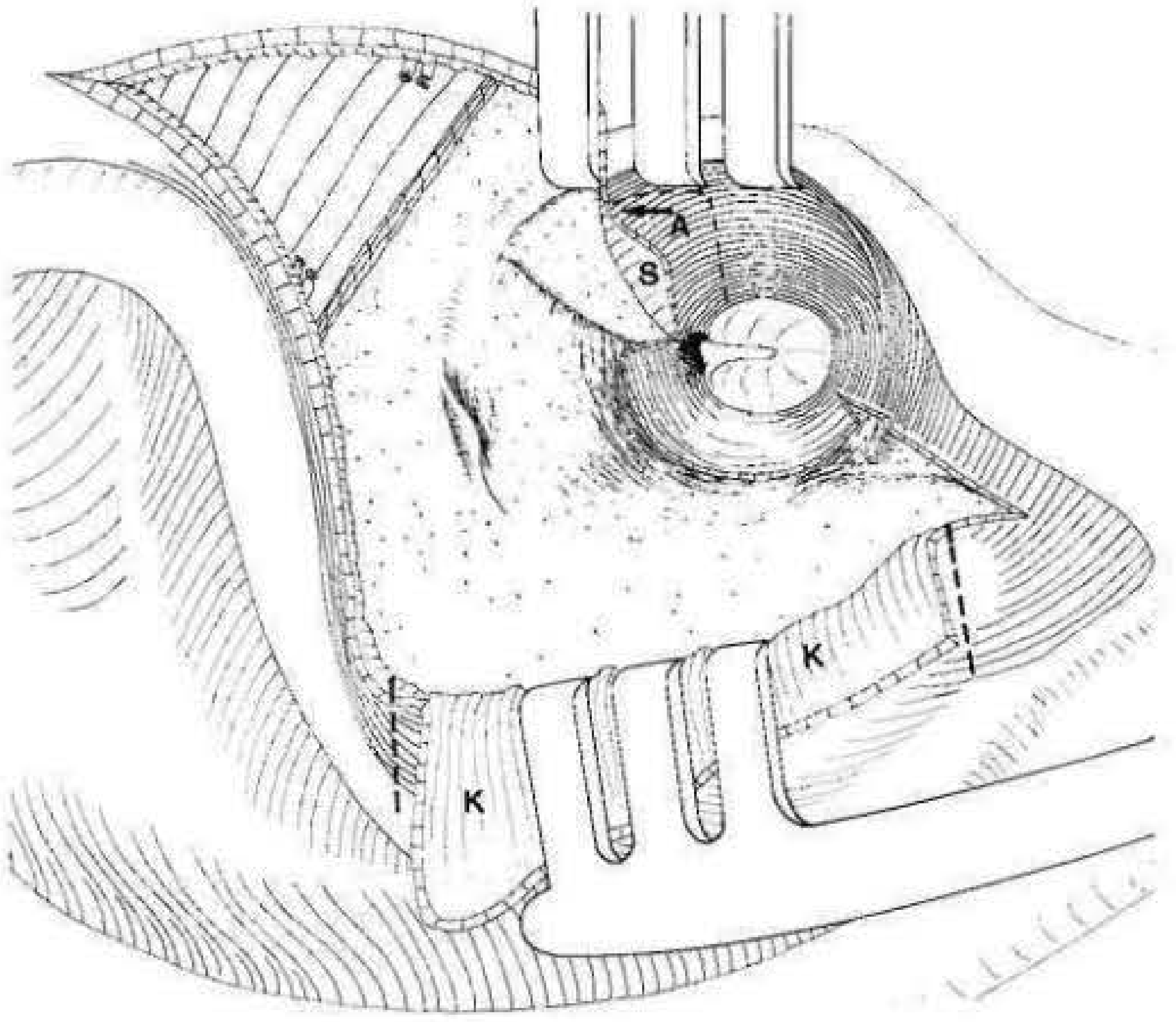


Fig. **746** **The Körner flap in an endaural approach.** The Heermann B incision, illustrating the laterally-based Körner flap (K), which can be enlarged using incisions through the conchal skin and conchal cartilage (dashed lines). Medially, a tympanomeatal flap is left, and superiorly, a small superior flap (S), which can be enlarged by two separate incisions in the anterior ear canal wall (A) and placed on the tegmen tympani (arrow)

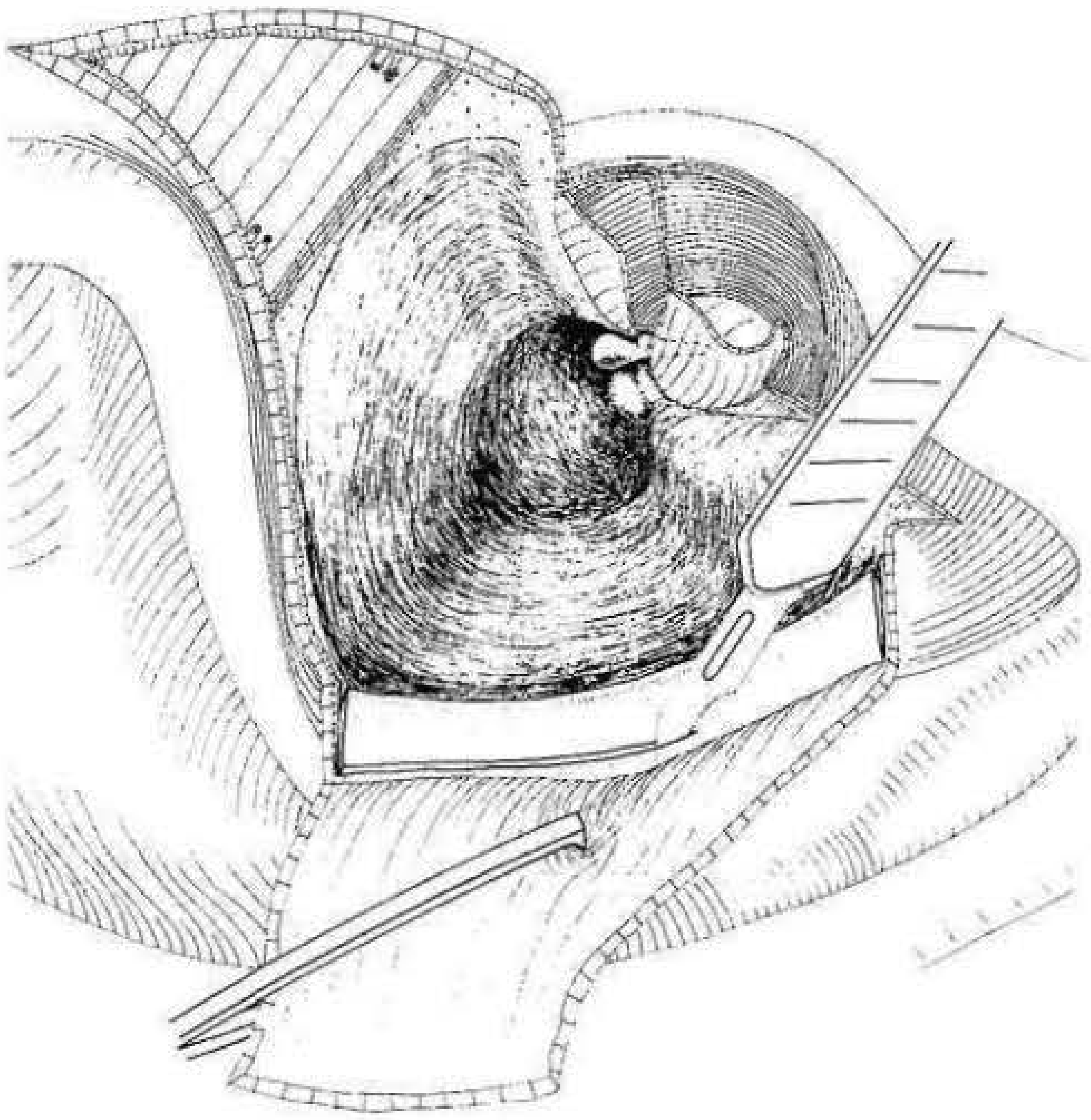


Fig. **747** **The meatoplasty in an endaural approach** enlarging the Körner flap. The conchal canal skin is elevated, and a 0.5-cm wide strip of the conchal cartilage is excised in a canal wall–down mastoidotomy situation with a preserved malleus head and elevated tympanomeatal flap

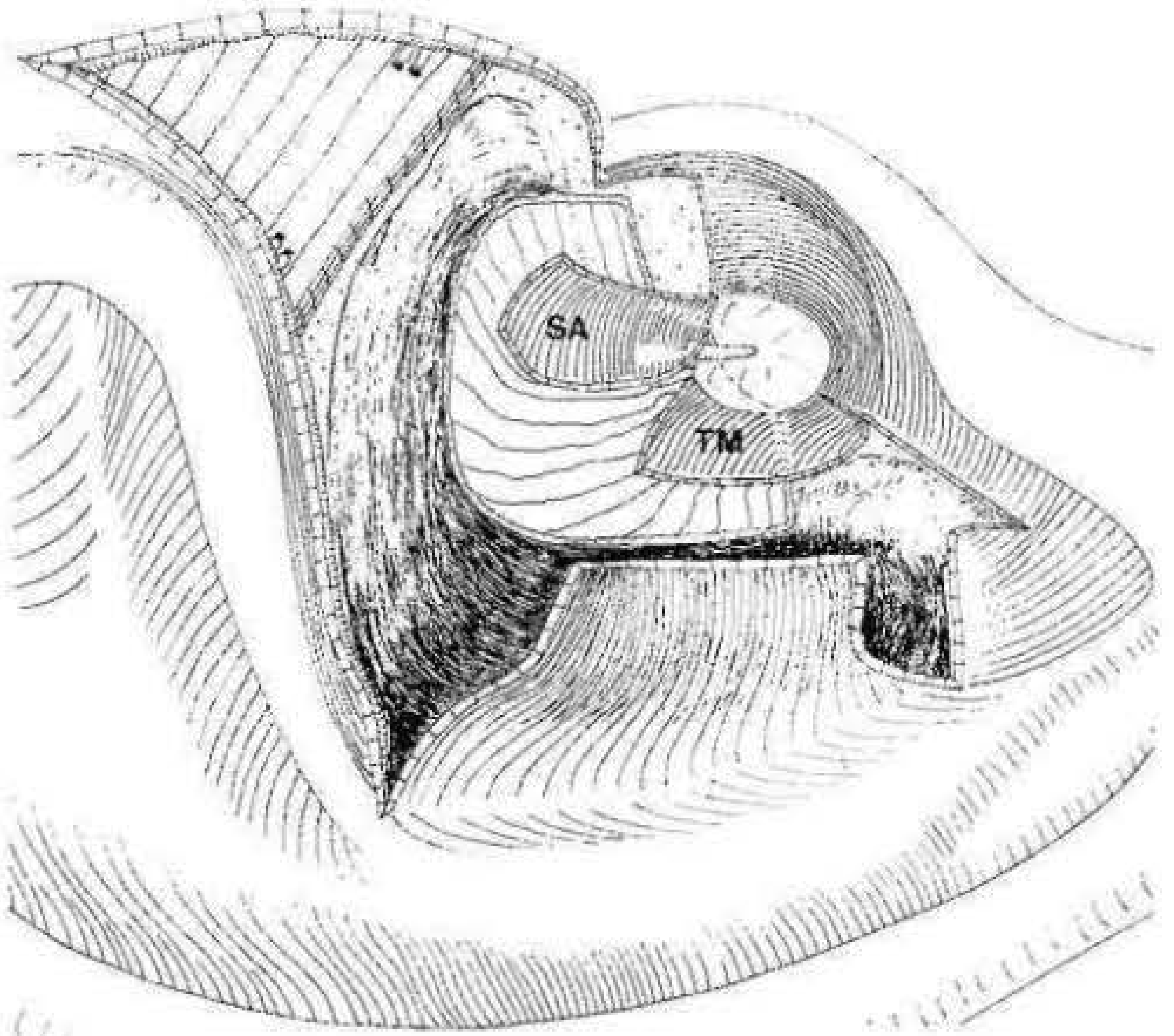


Fig. **748** **Reconstruction of an endaural canal wall–down mastoidectomy using the Körner flap,** which covers the posterior part of the cavity. Superiorly, a superoanterior skin flap is covering the attic (SA), and medially, a tympanomeatal flap (TM) is covering the aditus ad antrum

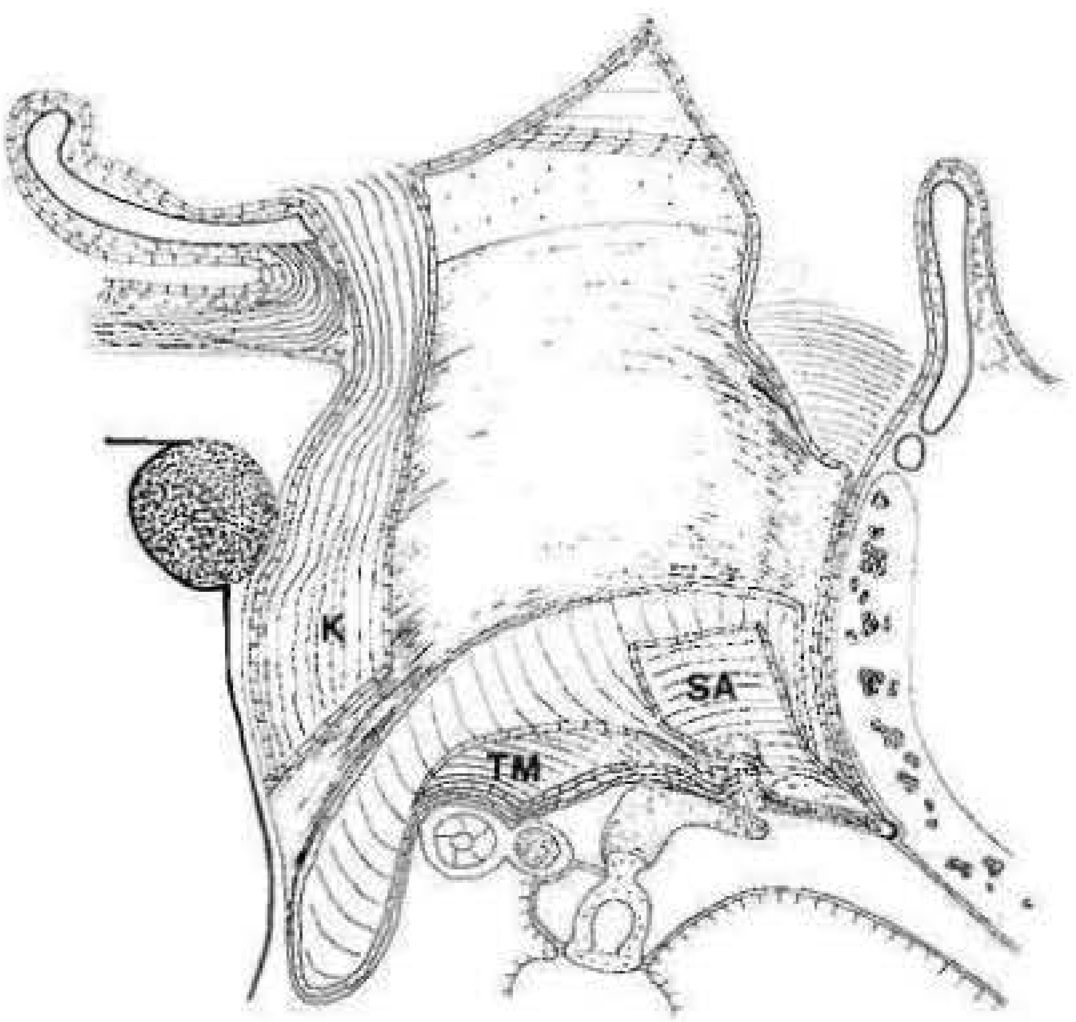


Fig. **749** Side view, with some perspective, of an endaural canal wall–down mastoidectomy, showing the placement of the Körner flap (K) on the posterior wall of the mastoid cavity. The medial wall is covered by fascia and the tympanomeatal flap (TM), as well as the superoanterior flap (SA)

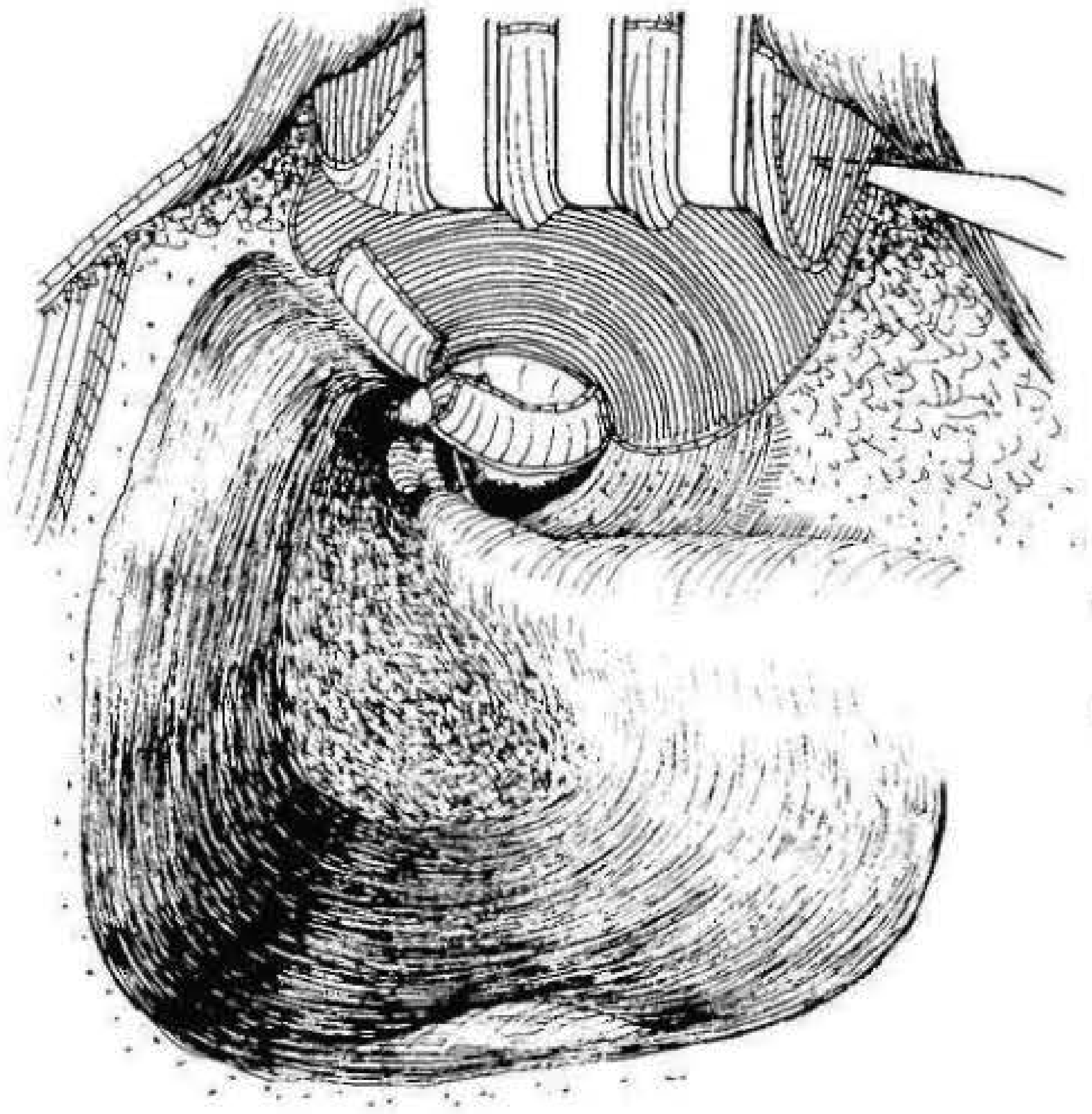


Fig. **750** **Creation of the Körner flap in a retroauricular canal wall–down mastoidectomy.** The medial part of the Körner flap is elevated, and the radial incisions at the 6-o'clock and 12-o'clock positions are extended into the conchal cartilage

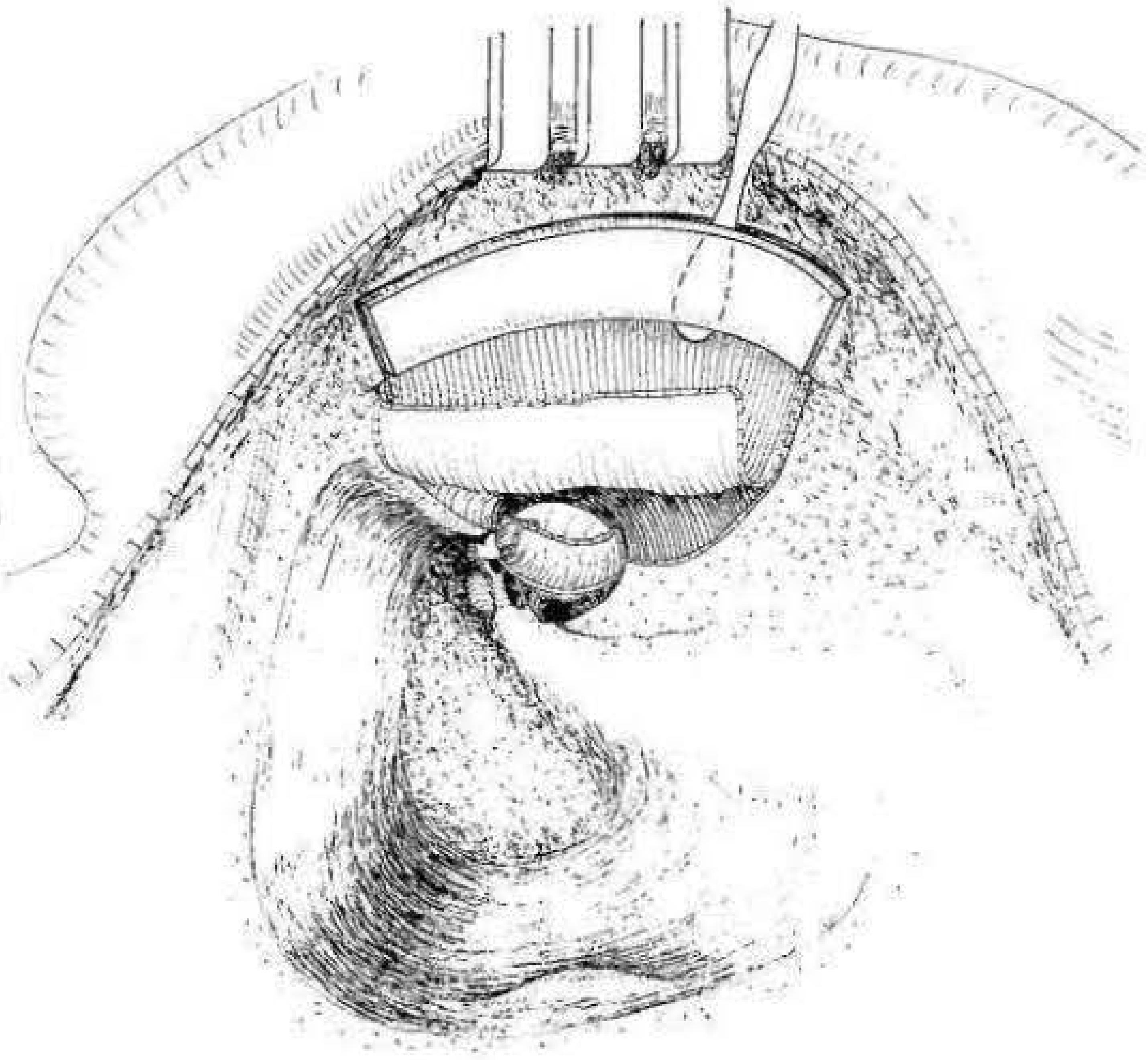


Fig. **751** **Meatoplasty in a retroauricular canal wall–down mastoidectomy** with preparation of a Körner flap. On the posterior aspect of the ear canal, the fibrous tissue is removed, the conchal cartilage is exposed, and a strip of conchal cartilage 0.5–1.0 cm wide is excised and elevated from the perichondrium using a Freer rugine

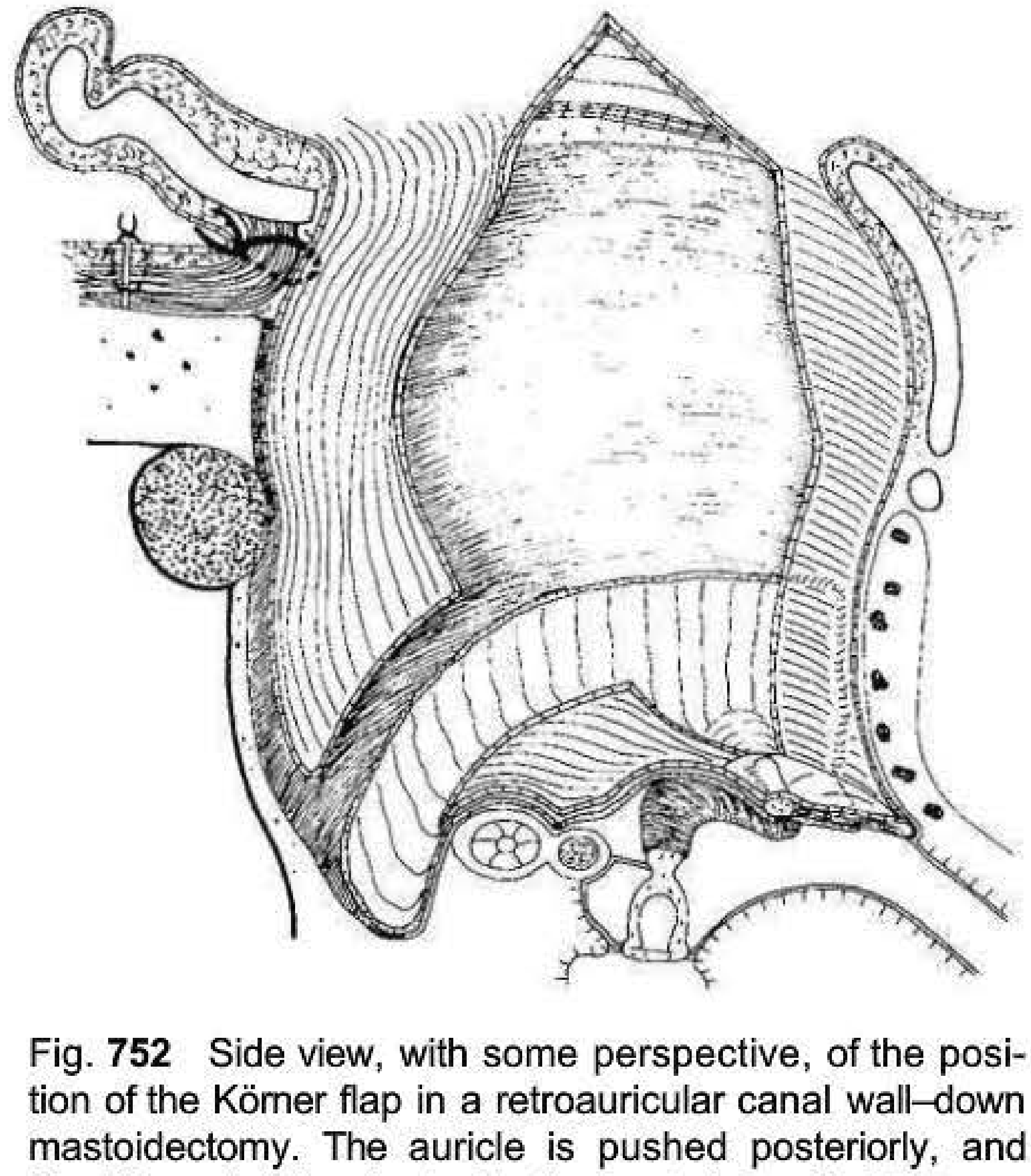


Fig. **752** Side view, with some perspective, of the position of the Körner flap in a retroauricular canal wall–down mastoidectomy. The auricle is pushed posteriorly, and the Körner flap is adapted to the posterior wall of the cavity and sutured to the auricular fibrous tissue with a relatively thick catgut suture

The Surdille Flap

The medially-based Surdille flap is the flap usually used in an endaural approach, and is described in Volume 1, Chapter 3. If a circumferential incision in the Heermann B, Lempert, Shambaugh, or Farrior modifications of the endaural approach is placed laterally, then a large Surdille flap is created, involving the entire posterior ear canal skin (Figs. **659–662**). The Shambaugh and Lempert incisions run laterally at the level of the suprameatal spine, and the lateral part of the ear canal skin, the conchal canal skin flap, or the Körner flap, are therefore not present (Figs. **660**, **661**). In Farrior's endaural incision, however, the Surdille flap is somewhat smaller (Fig. **662**); the conchal canal skin flap, on the other hand, is relatively large. In fact, Farrior performed his meatoplasty by excising a small strip of conchal cartilage at the beginning of the surgery. The Farrior meatoplasty is based on a conchal skin flap (a small Körner flap), which is enlarged by excision of the cartilage and creation of a subcutaneous tissue flap (Vol. 1, Figs. **58–60**).

By adding a radial incision, the Surdille flap can be divided into an inferior and a superior half. The superior half covers the attic (Fig. **753**), and the inferior half covers the facial ridge.

The Stacke Flap

The Stacke flap is inferiorly based, and consists of posterior ear canal skin and a strip of the conchal cartilage. The Stacke flap is performed using a retroauricular approach, making a radial incision at the 12-o'clock position, a medial circumferential incision 2–3 mm lateral to the drum, and a lateral circumferential incision through the conchal cartilage (Fig. **754**). The conchal cartilage is removed, and the Stacke flap covers the entire facial ridge and the inferior part of the cavity (Fig. **755**).

In an endaural approach, the Stacke flap does not include the conchal cartilage (Chapter 9, Figs. **533**, **537**, **539**, **541**, **543–546**). The ear canal skin is thick laterally, and has to be thinned in order to be adapted to the cavity wall.

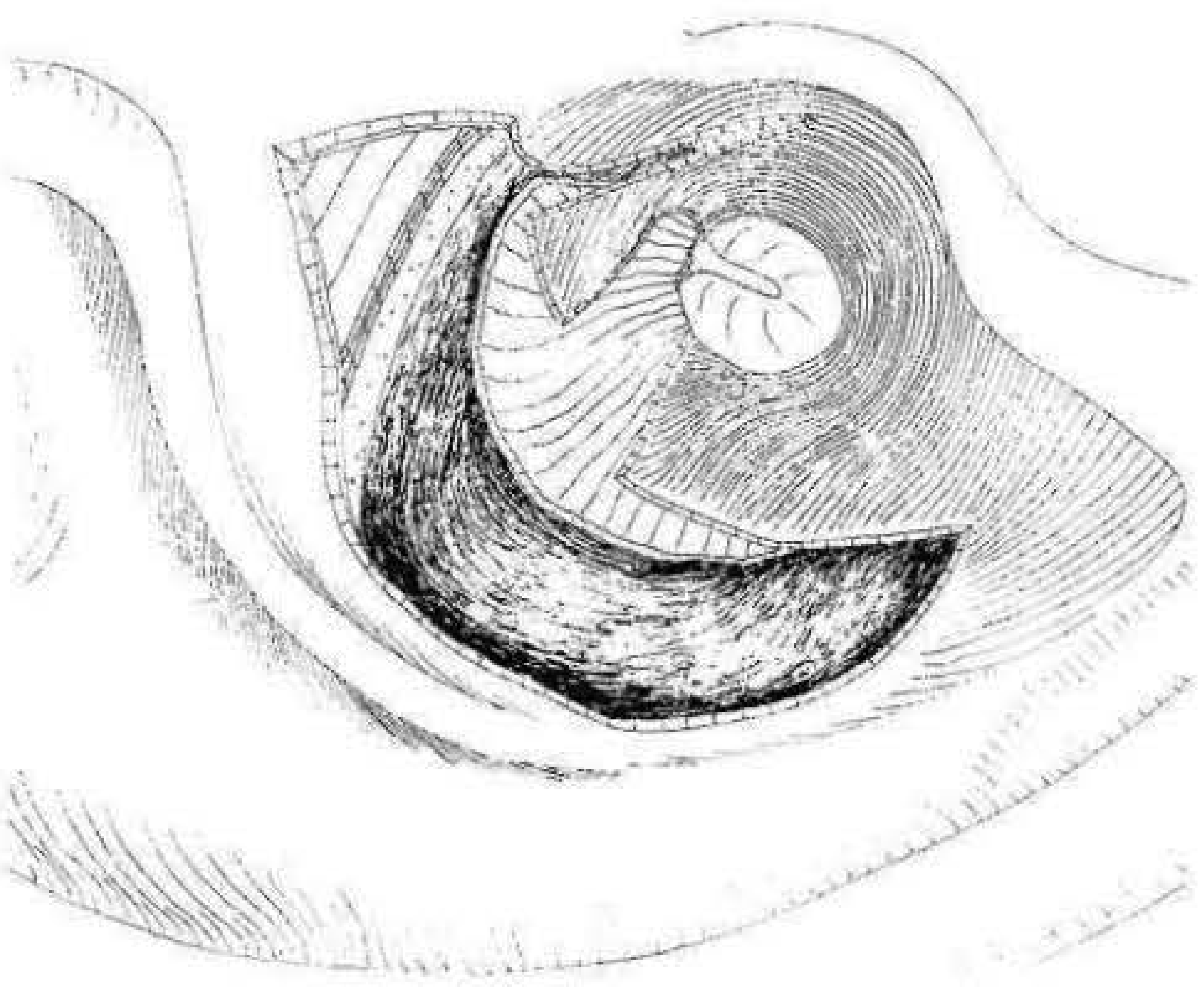


Fig. **753** **The Surdille flap** divided into two parts in endaural canal wall–down mastoidectomy using a Shambaugh incision. The inferior part of the flap covers the facial ridge, and the superior part covers the anterior attic

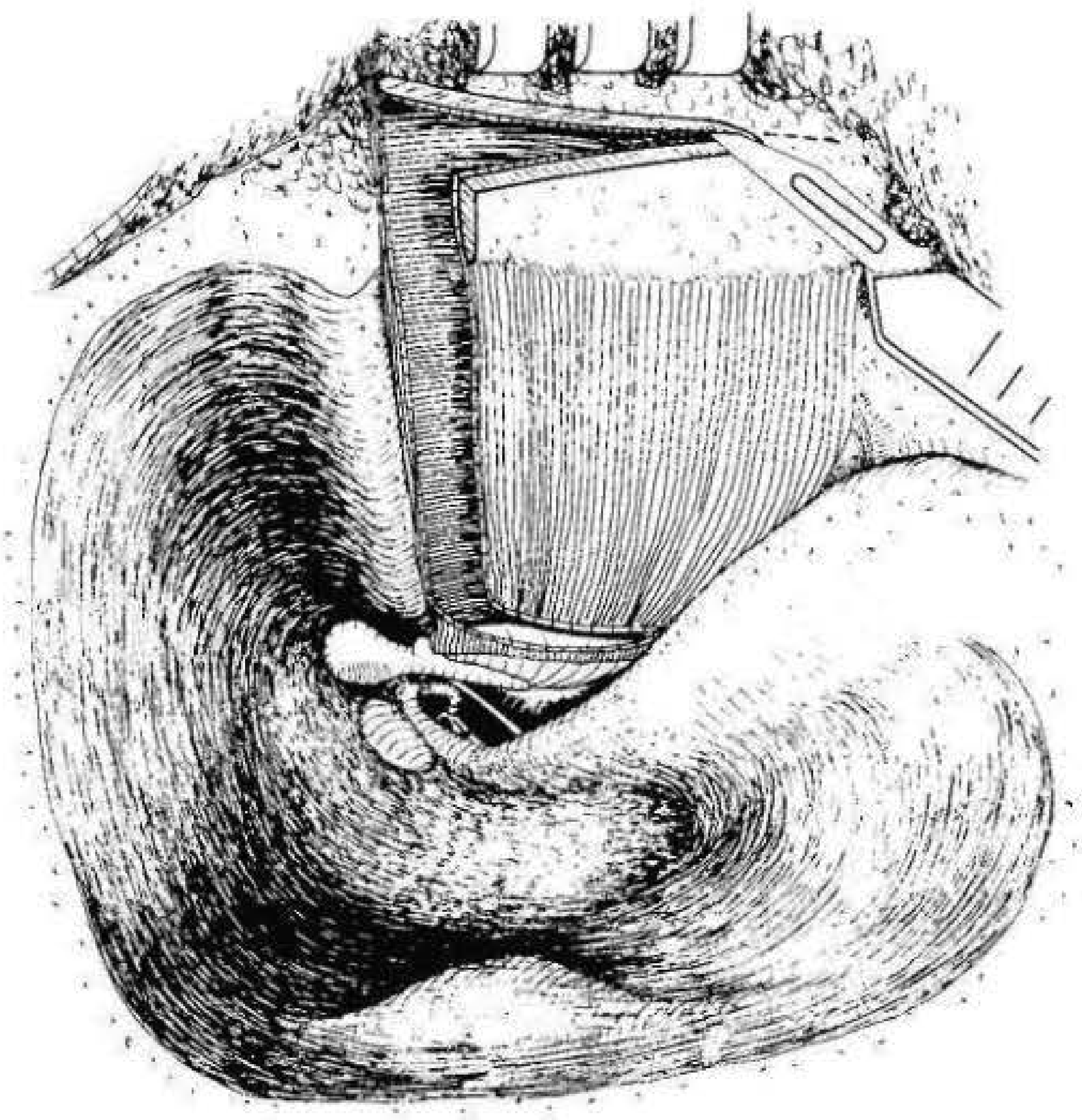


Fig. **754** **The Stacke flap in a retroauricular approach.** A vertical incision is made at the 12-o'clock position, a medial circumferential one close to the drum, and a lateral one through the anterior edge of the conchal cartilage and the ear canal skin. The flap is inferiorly based, and after placement of the auricle in its original position it will cover the inferior part of the cavity. The cartilage has to be excised, and the thick lateral part of the ear canal skin has to be thinned

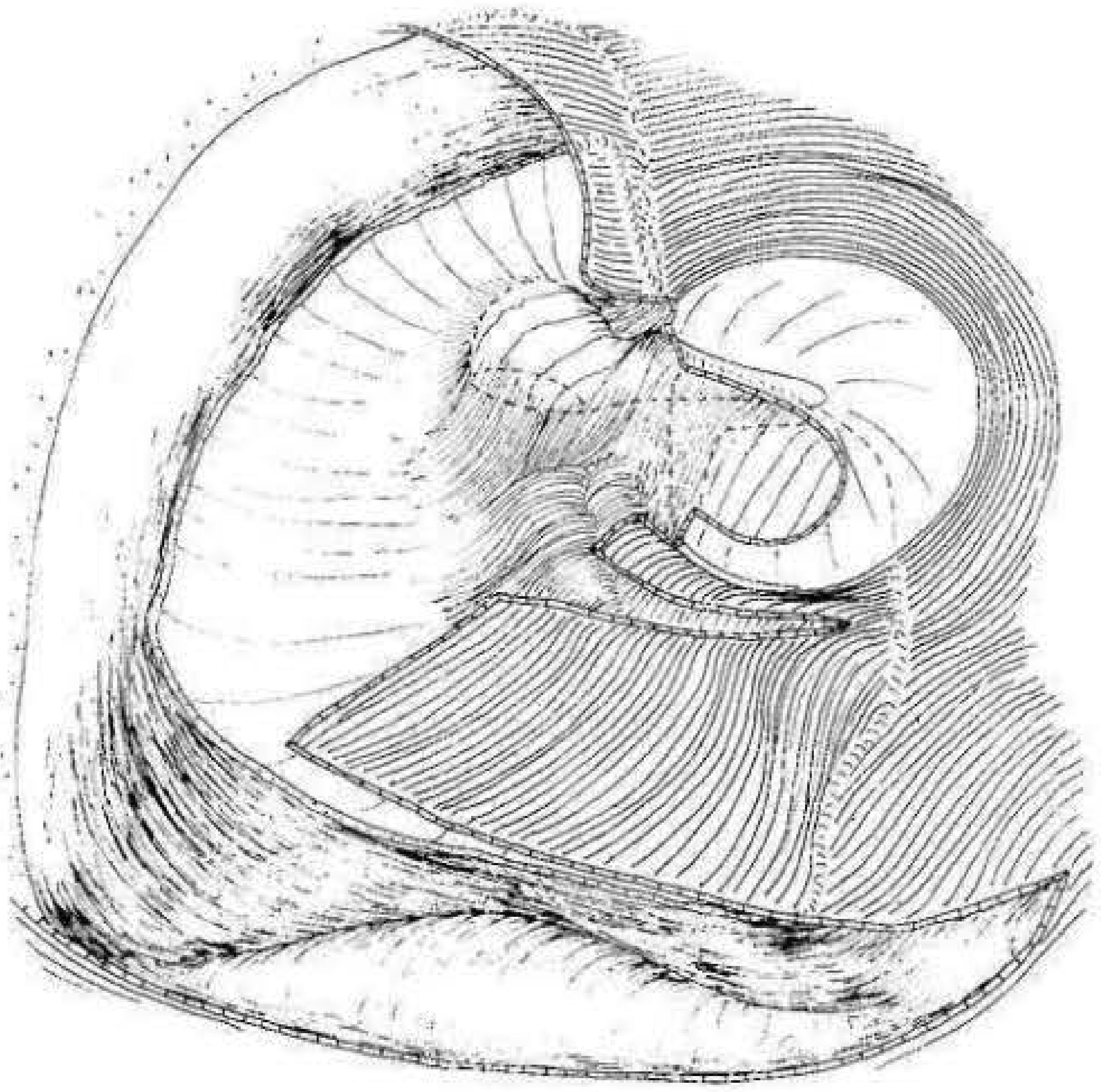


Fig. **755** A canal wall–down mastoidectomy with the Stacke flap covering the inferior part of the canal wall down cavity

Meatoplasty

The meatoplasty is usually the final stage of a canal wall–down mastoidectomy with an open cavity technique. The meatoplasty ensures sufficient enlargement of the external auditory meatus, and mobilizes the upper part of the auricle in order for it to be pulled or pushed posteriorly, depending on the approach used. It also allows for the creation and placement of ear canal skin flaps for cavityplasty.

For all types of meatoplasty, an intercartilaginous incision at the 12-o'clock position is used, and in fact it is this incision that mobilizes the pinna.

In an *endaural approach,* the intercartilaginous incision has already been performed, and the pinna is already displaced posteriorly during the approach, so that part of the meatoplasty is already done (Figs. **659–662**). This is probably one of the reasons that the endaural incision is so popular.

In a *retroauricular approach,* the pinna is pushed anteriorly, and the external auditory meatus is compressed by a selfretaining retractor, holding the pinna in an anterior position. The pinna has to be liberated prior to meatoplasty, which usually results in some bleeding, so that the work in the tympanic cavity has to be completed first—i. e., placement of the fascia under the drum and onto the medial part of the cavity, replacement of the medial tympanomeatal flap, and possibly placement of the Stacke flap as well as the superior or anterior ear canal skin flaps. The *medial part* of the ear canal and the cavity has to be firmly packed before starting the meatoplasty, otherwise bleeding during meatoplasty, which requires suction, could result in disruption of the fascia and the canal skin flaps.

Endaural Approach

Several meatoplasty procedures have been described that are used in an endaural approach. As mentioned previously, the main part of the meatoplasty has already been performed in the endaural approach, in order to perform the mastoidectomy. The goal of the meatoplasty is to maintain a widened external auditory meatus and to guide epithelialization of the posterior and superior parts of the cavity.

The Körner flap meatoplasty has already been described in Figures **746–749,** and is based on the resection of the conchal cartilage and enlargement of the posterolaterally-based canal skin flap, which is already present and relatively long. After resection of the cartilage, the posterior Körner flap can easily be adapted to the posterior wall of the cavity and held in place by packing.

The Stacke meatoplasty in the endaural approach has already been illustrated in Figures **754** and **755.** Here, too, a strip of conchal cartilage is resected in order to enlarge the external auditory meatus.

The Farrior meatoplasty. As mentioned previously, Farrior's procedure is to create a conchal–ear canal skin flap and enlarge it by incorporating a subcutaneous tissue flap (Fig. **662**). Farrior recognizes the importance of encouraging the epithelialization of the cavity from the posterior edge of the cavity along the posterior fossa dura (Fig. **756**). The Farrior conchal flap is considerably shorter than the Körner flap, but with the subcutaneous tissue as a continuation of the epithelial flap, it remains in position. Medially, a large area of the medial attic wall can be covered, because the Surdille flap raised in the Farrior incision is larger than the tympanomeatal flap raised in the Heermann B incision.

The Fleury meatoplasty. Using a Fleury incision with a superior vascular strip (Vol. 1, Figs. **67** to **71**), a large Surdille flap is created. In canal wall–down mastoidectomy, this Surdille flap, which is created by a radial incision at the 12-o'clock position, is large, and it covers the facial ridge and the lower part of the cavity. Fleury recognized the difficulties in epithelialization of the posterior part of the cavity when there is no flap, and therefore created his meatoplasty in the following way: First, the vertical incision is sutured, pulling the upper part of the auricle upward in order to obtain correct approximation and prevent displacement of the auricle. The meatus is then enlarged by elevating the conchal skin and exposing a strip of conchal cartilage. The conchal cartilage is then resected after subperichondral undermining of the cartilage (Fig. **757**).

Two incisions are made through the conchal skin and perichondrium (Fig. **758**) allowing folding of the skin and perichondrium around the exposed conchal cartilage (Fig. **759**). The folded skin is now fixed using special sutures around the edge of the cartilage incorporating a small piece of gauze (Fig. **759**). The ear canal is thus enlarged and the conchal skin flap is directed into the proper position (Fig. **760**).

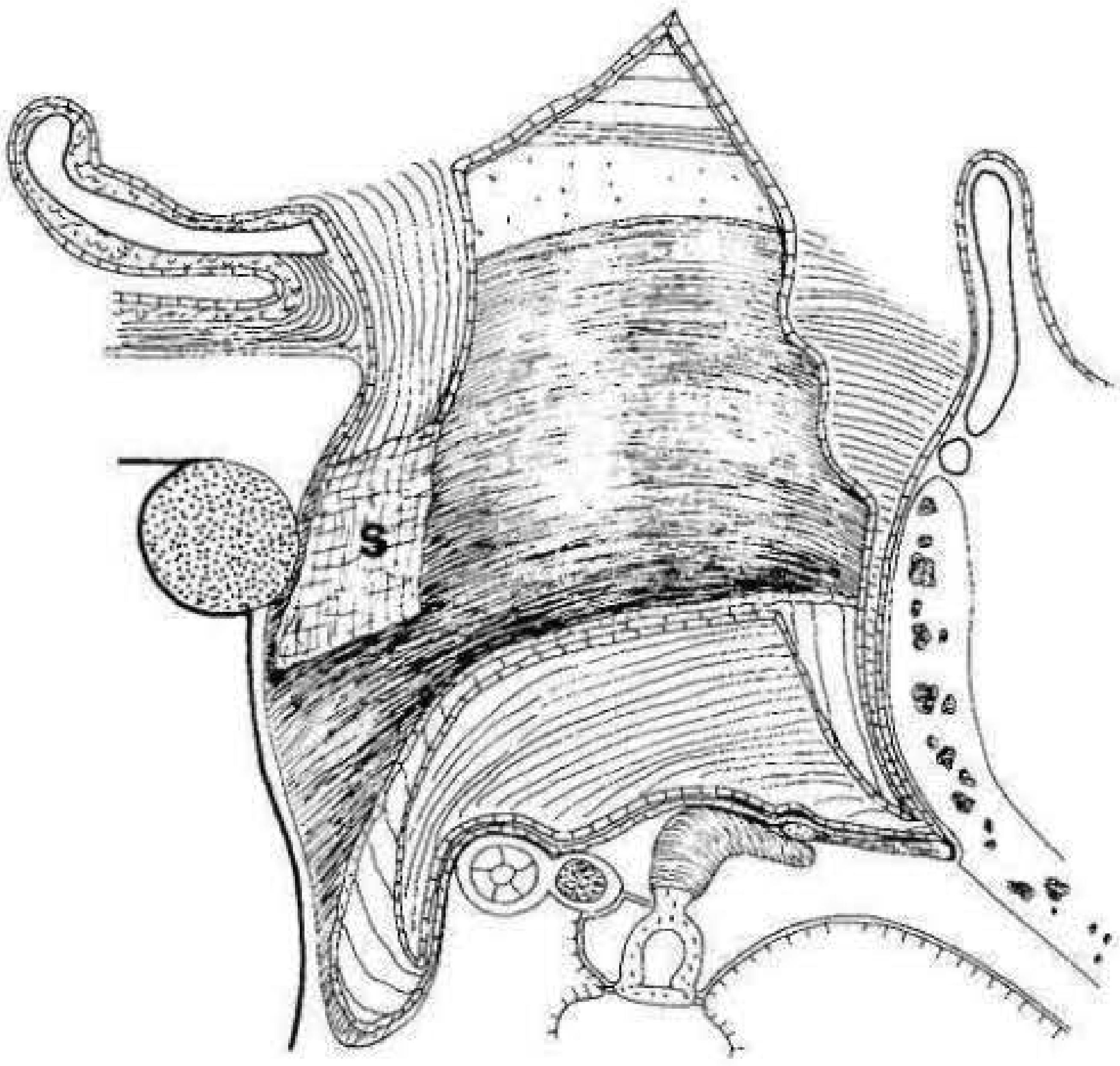


Fig. **756** **A Farrior meatoplasty in an endaural approach.** Side view, with some perspective. The conchal flap is extended using a flap consisting of subcutaneous tissue (S) and placed on the posterior aspect of the cavity after resection of the conchal cartilage. The medial wall of the cavity is partly covered with a large Surdille flap

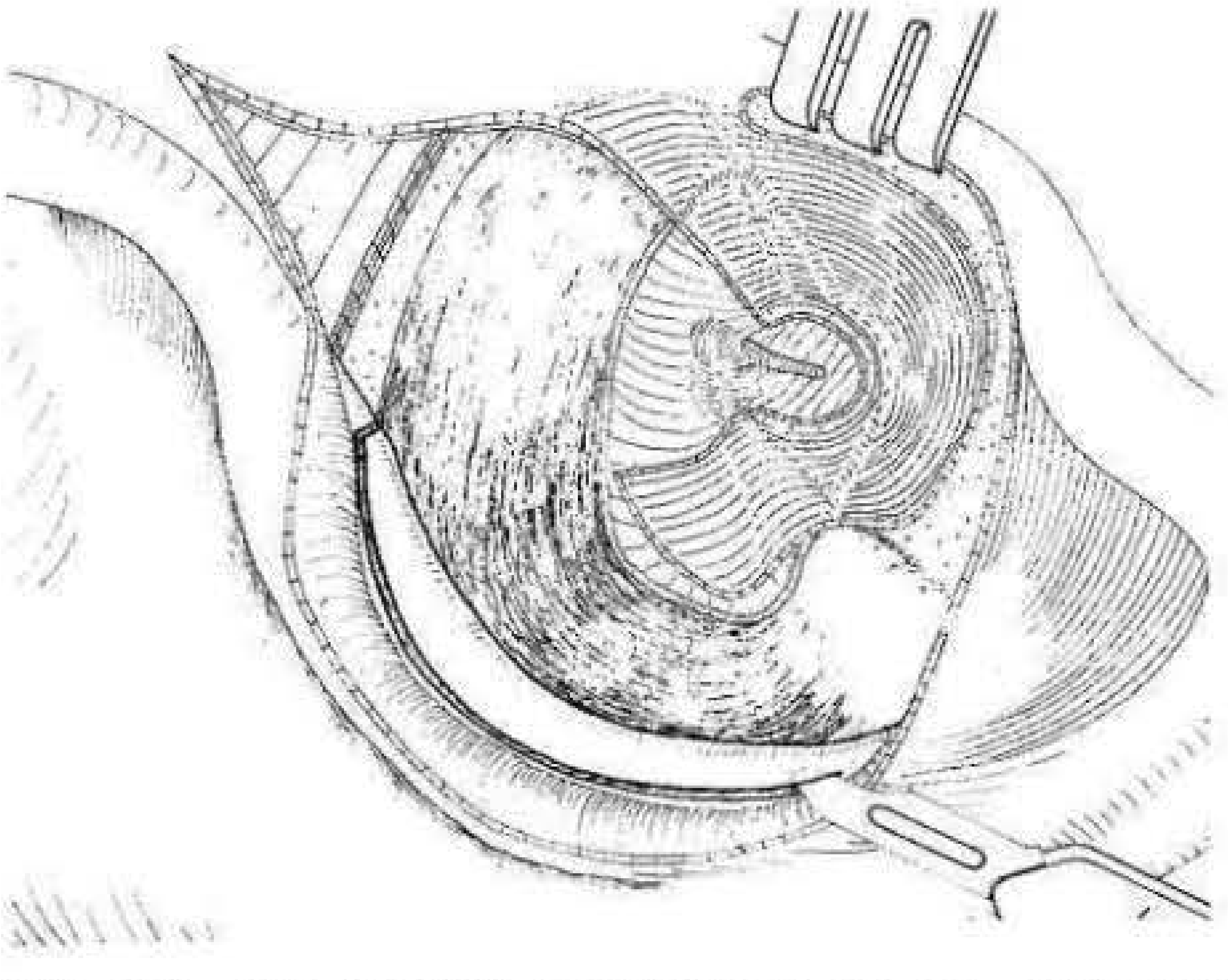


Fig. **757** **The Fleury meatoplasty in an endaural approach.** First, a large Surdille flap is placed on the medial wall of the cavity. The anterior part of the attic is covered with a piece of fascia placed under the drum; the fascia also covers the resected malleus and tegmen antri. Then the pinna is brought into its original position by placing a suture at the vertical incision. The conchal skin with the perichondrium is elevated, exposing the anterior 0.5 cm of the concha, including the anterior border of the crus of the helix. The conchal cartilage, together with the fibrous tissue attached to its posterior aspect, is excised using a knife

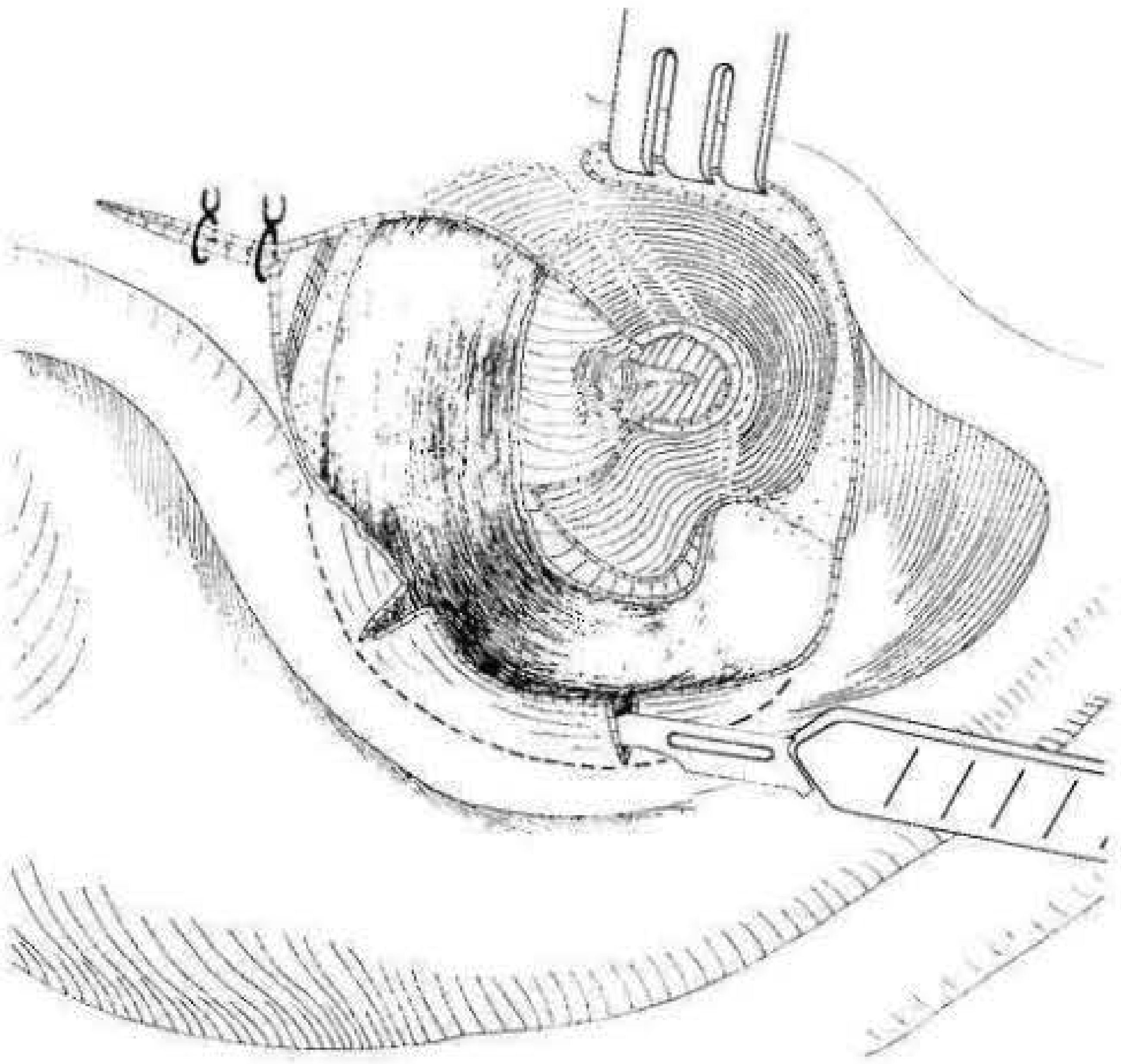


Fig. **758** Two incisions are made through the conchal skin, allowing liberation of a superior and inferior skin flap, which are folded under the remaining conchal cartilage. The extent of the resection of the conchal cartilage and the position of the new conchal cartilage edge are indicated by the dashed line

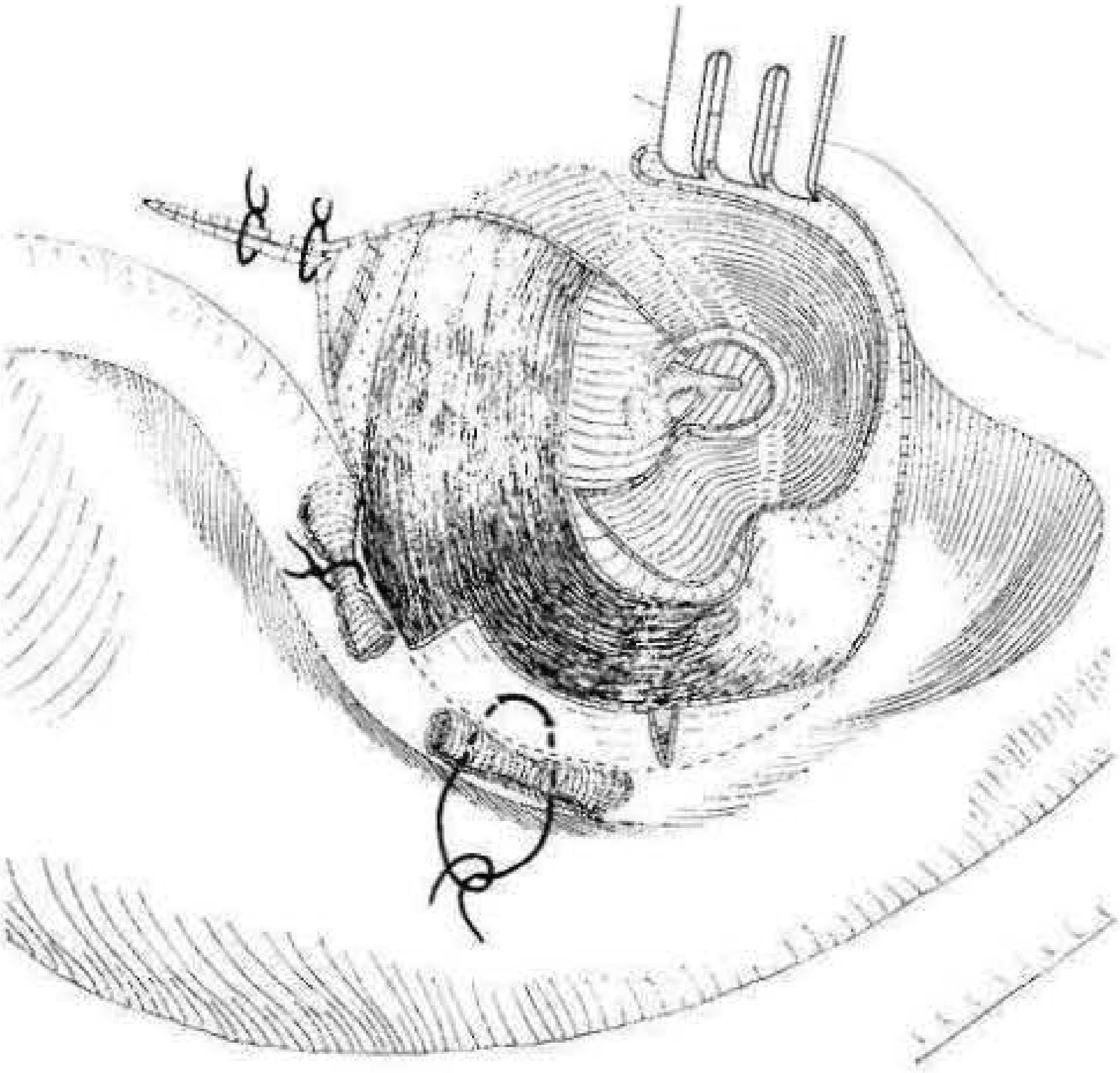


Fig. **759** The freed conchal skin flap is inverted around the edge of the conchal cartilage, and fixed with a special transfixing suture going through the conchal skin anteriorly and the conchal cartilage and inverted conchal skin flap posteriorly. The transfixing suture is tightened over a small piece of gauze

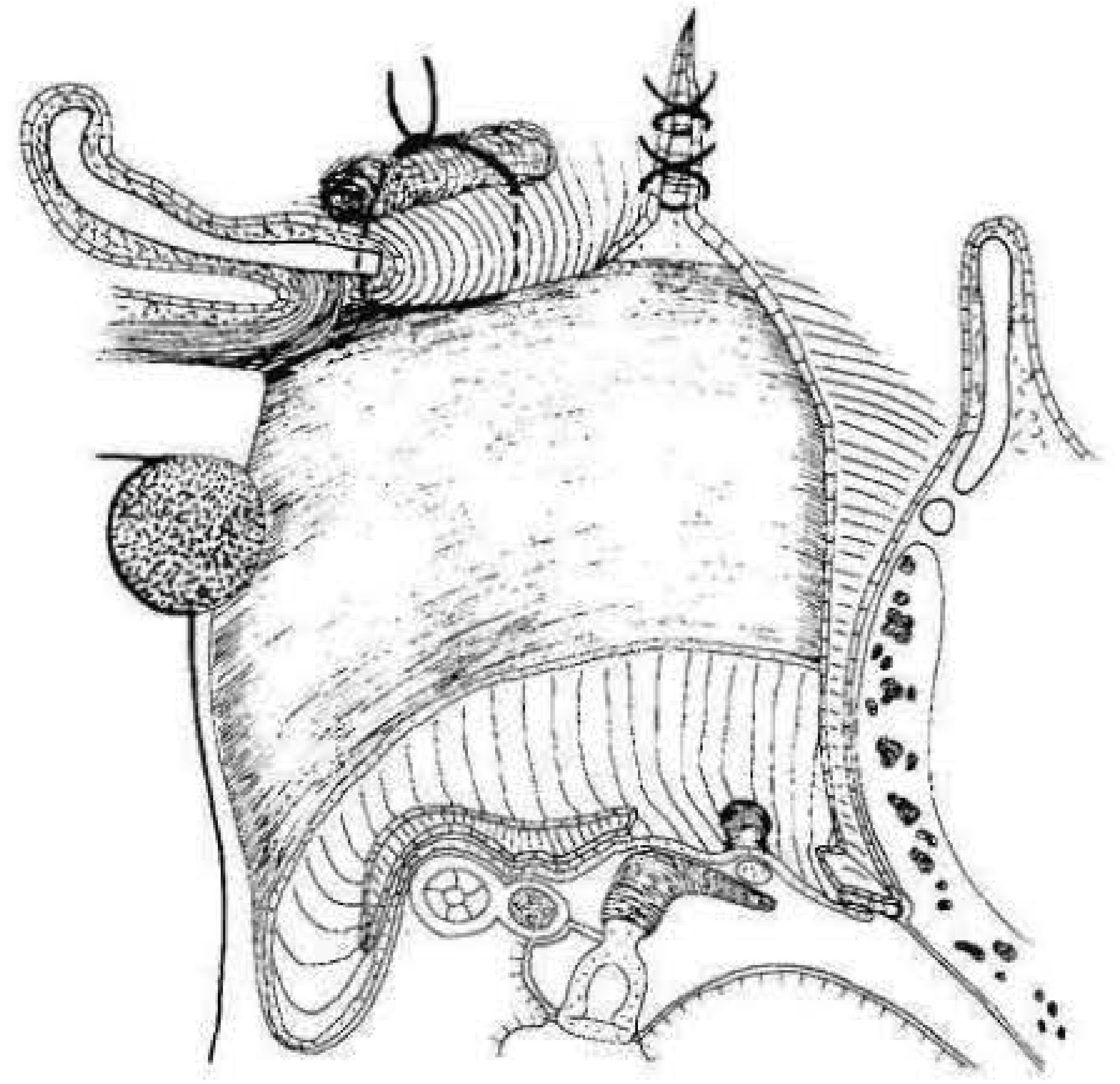


Fig. **760** **Side view, with some perspective, of the Fleury meatoplasty.** The fixation of the superior conchal flap goes through the skin and the conchal cartilage. The epithelial flap will epithelialize the posterior and superior aspects of the cavity. Medially, a large Surdille flap is covering the medial attic wall and the tegmen tympani. Ossiculoplasty with a shaped incus and myringoplasty with an underlay fascia graft are performed

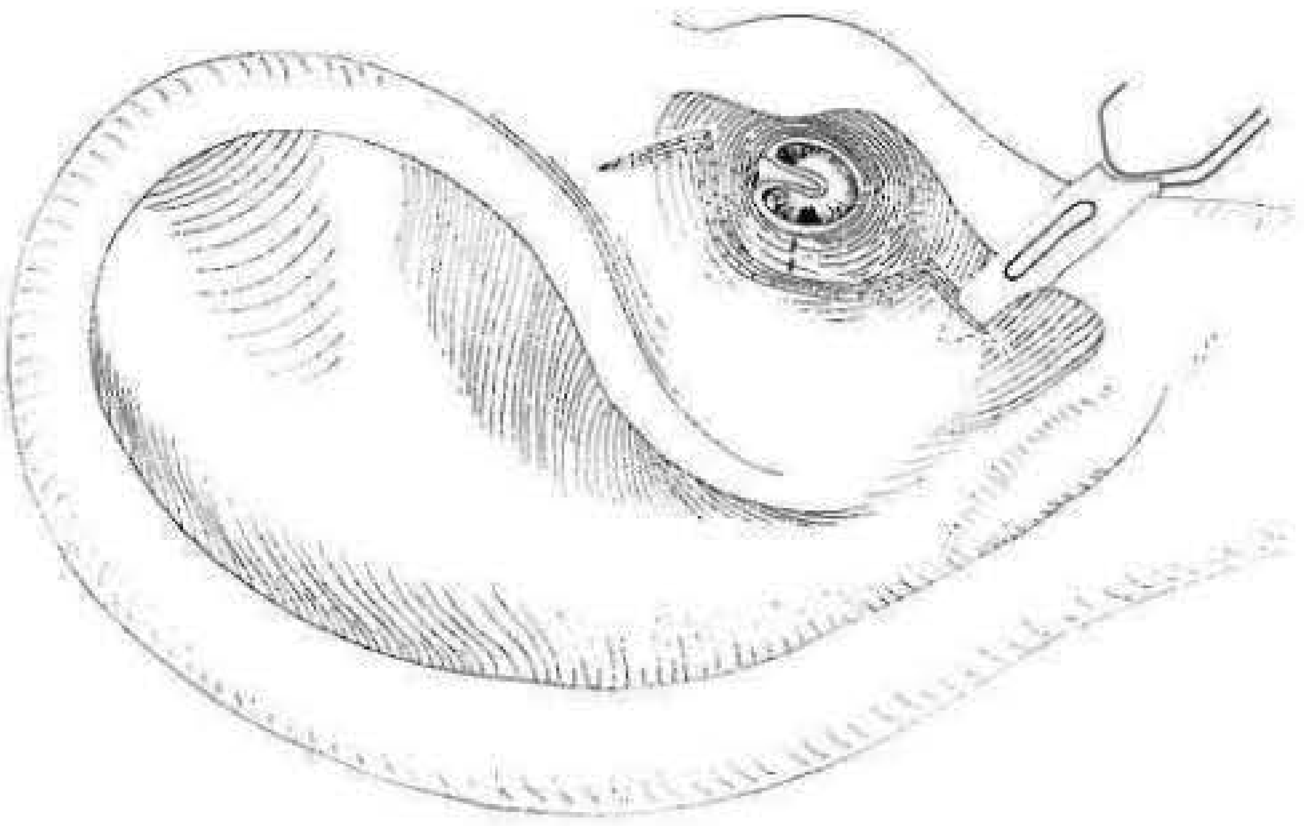


Fig. **761** **The Portmann small (three-flap) meatoplasty without cartilage removal in a retroauricular approach.** A lateral circumferential incision is made between the 12-o'clock and 6-o'clock positions. From the upper edge of the incision, a lateral vertical incision continues along the 12-o'clock position toward the helix, and at the 6-o'clock position an inferior incision continues into the concha, allowing elevation of a laterally based flap

Retroauricular Approach

The techniques for resection of the conchal perichondrium and cartilage in the retroauricular approach, as well as the lines of resection, are illustrated in Volume 1, Figures **267–288**.

The Körner flap meatoplasty is described in Figures **750–753**).

The Stacke meatoplasty is described in Figures **754** and **755**.

Portmann's small three-flap meatoplasty. This meatoplasty is based on the use of three flaps, a lateral, a superior, and an inferior flap, without removal of any conchal cartilage. It is used in small cavities. A lateral circumferential incision between the 1-o'clock and 6-o'clock positions is made about 10 mm lateral to the upper drum. An upper lateral radial incision is made from the upper part of the circumferential incision toward the spine of the helix and a similar lower incision runs from the inferior edge of the circumferential incision toward the concha (Fig. **761**). A canal wall–down mastoidectomy is performed. The meatoplasty is started by placing a finger through the ear canal, exposing the lateral flap, which is cleaned and made thinner using a pair of scissors. When this is completed, the edge of the conchal cartilage will be visible, and the laterally based flap is turned around the cartilage and fixed to the posterior aspect of the cartilage with two catgut sutures. This flap will form the lateral covering of the cavity. The ear canal skin is now divided at the 9-o'clock position down to the drum, creating a superior and an inferior flap (Fig. **762**).

After performing the tympanoplasty, placing fascia on the medial wall of the cavity and positioning the superior and inferior ear canal skin flaps (Fig. **763**), the auricle is replaced and sutured back into position. The laterally-based flap is now in place, the inferior flap covers the facial ridge, and the superior flap covers the superior part of the cavity. It is important to carry out extensive thinning of the inferior and superior ear canal skin flaps in order to avoid a spring action arising in the flaps, which would tend to encourage them back into their natural position. If the skin flaps are thin enough, they will remain in position after appropriate packing of the ear.

Portmann's large five-flap meatoplasty with removal of cartilage. If the cavity is very large, the ear canal must also be wider, requiring more extensive removal of the cartilage. The meatoplasty starts with a Y-shaped incision. The ear canal skin is incised at the 9-o'clock position, and the incision is directed from medial to lateral. Laterally, at the conchal cartilage, one incision turns inferoanteriorly, the other superoanteriorly (Fig. **764**), resulting in a laterally-based flap as well as a superior and an inferior flap, and these two flaps are further divided later. The conchal skin from the laterally-based flap—the posterior conchal flap—is elevated from the cartilage, which is exposed before a triangular piece of conchal cartilage is resected (Fig. **765**). Similarly, the skin from the two meatoconchal flaps—a superior and an inferior one—is elevated, exposing first the superior part of the conchal cartilage, which is resected with a pair of scissors (Fig. **766**), and then similarly the inferior part. In order to facilitate mobility of the two flaps, it is necessary to remove a triangle of skin from the apexes of each of the flaps at the junction between the concha and the meatus (Fig. **767**). Five flaps are thus created (Fig. **768**): the triangular posterior conchal flap; two meatoconchal flaps on each side, one superior and one inferior; and the two meatal flaps, one superior and one inferior. From their mastoid sides, the meatal flaps are thinned with a pair of scissors. The thinning helps the flaps to remain in position. The thinned flaps are turned backward and sutured with a single suture to the posterior aspect of the concha (Fig. **769**). The cavity is packed with gauze, moistened with antibiotics and hydrocortisone ointment, and the pinna is sutured to the posterior edge of the wound (Fig. **770**). Care should be taken not to displace or deform the pinna.

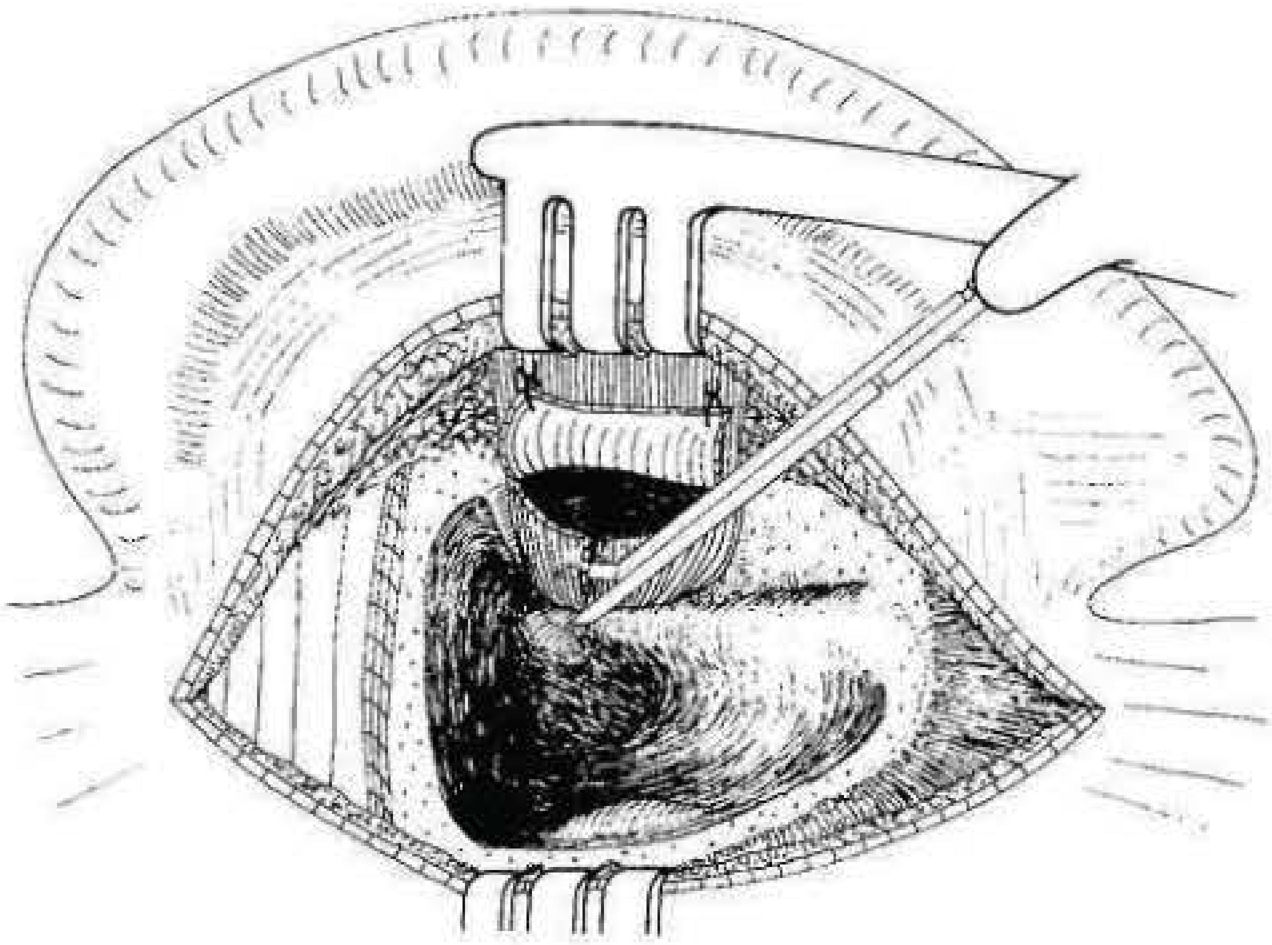


Fig. **762** Retroauricular aspect of the meatoplasty. The laterally-based conchal flap is trimmed, removing all the fibrous tissue on the surface of the conchal cartilage. The flap is folded on the posterior aspect of the conchal cartilage, and sutured with two catgut sutures. The posterior meatal skin is cut, resulting in a superior and an inferior meatal skin flap

The Sheehy meatoplasty (Sheehy 1988). A vertical incision is performed at the 12-o'clock position, running parallel to the crus of the helix. A horizontal incision passes backward at the 9-o'clock position through the conchal skin and cartilage and postauricular soft tissue, dividing the laterally-based skin flap

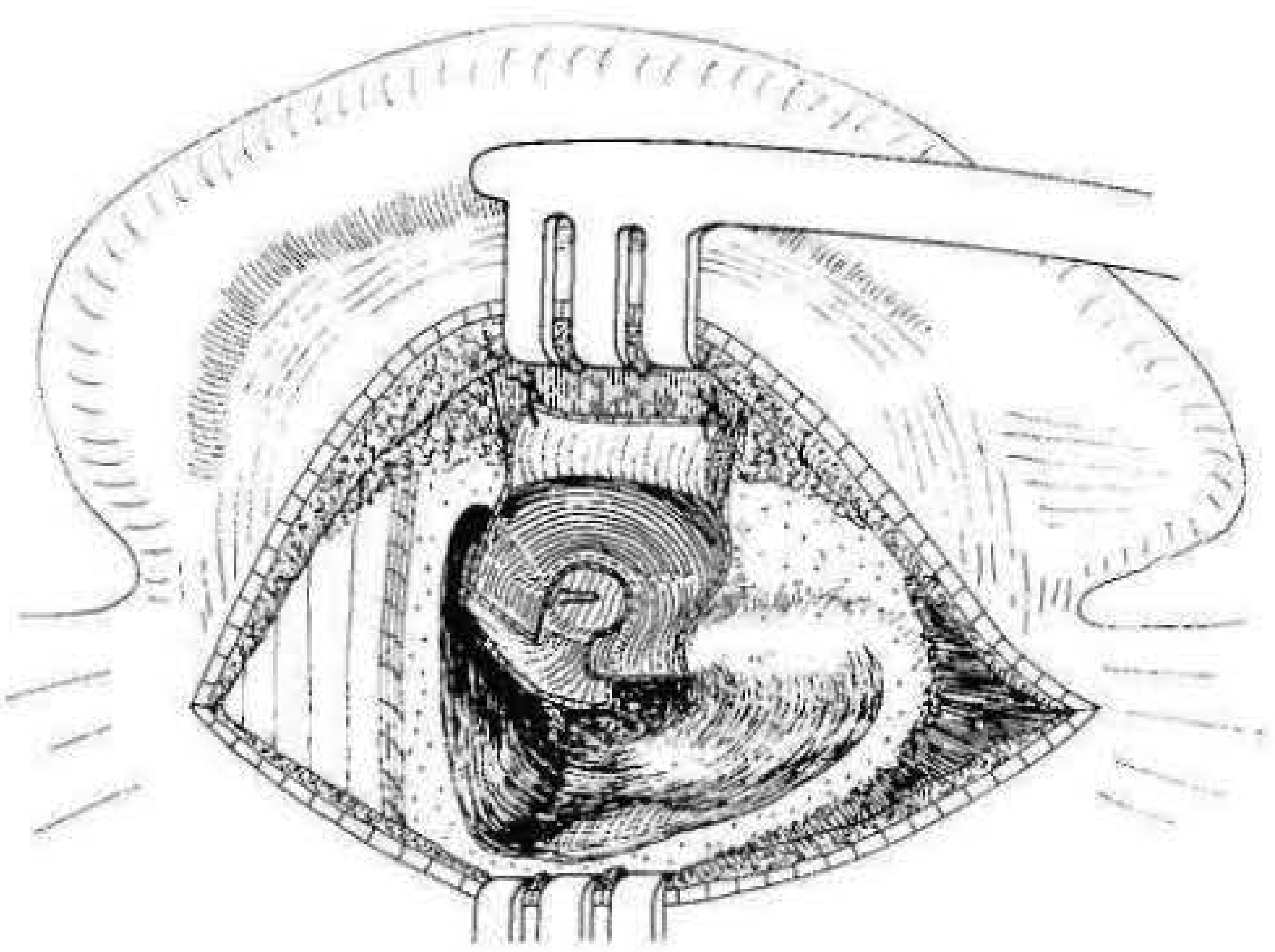


Fig. **763** The perforation is closed with an underlay fascial graft, also covering the medial wall of the attic and the lateral semicircular canal. The superior meatal flap is folded out, covering part of the superior cavity wall. The inferior flap mainly covers the facial ridge. The cavity can now be packed with Gelfoam balls or gauze, or both, through the ear canal, fixing the flaps into the desired position. Finally, the auricle is returned and fixed to the posterior edge of the wound

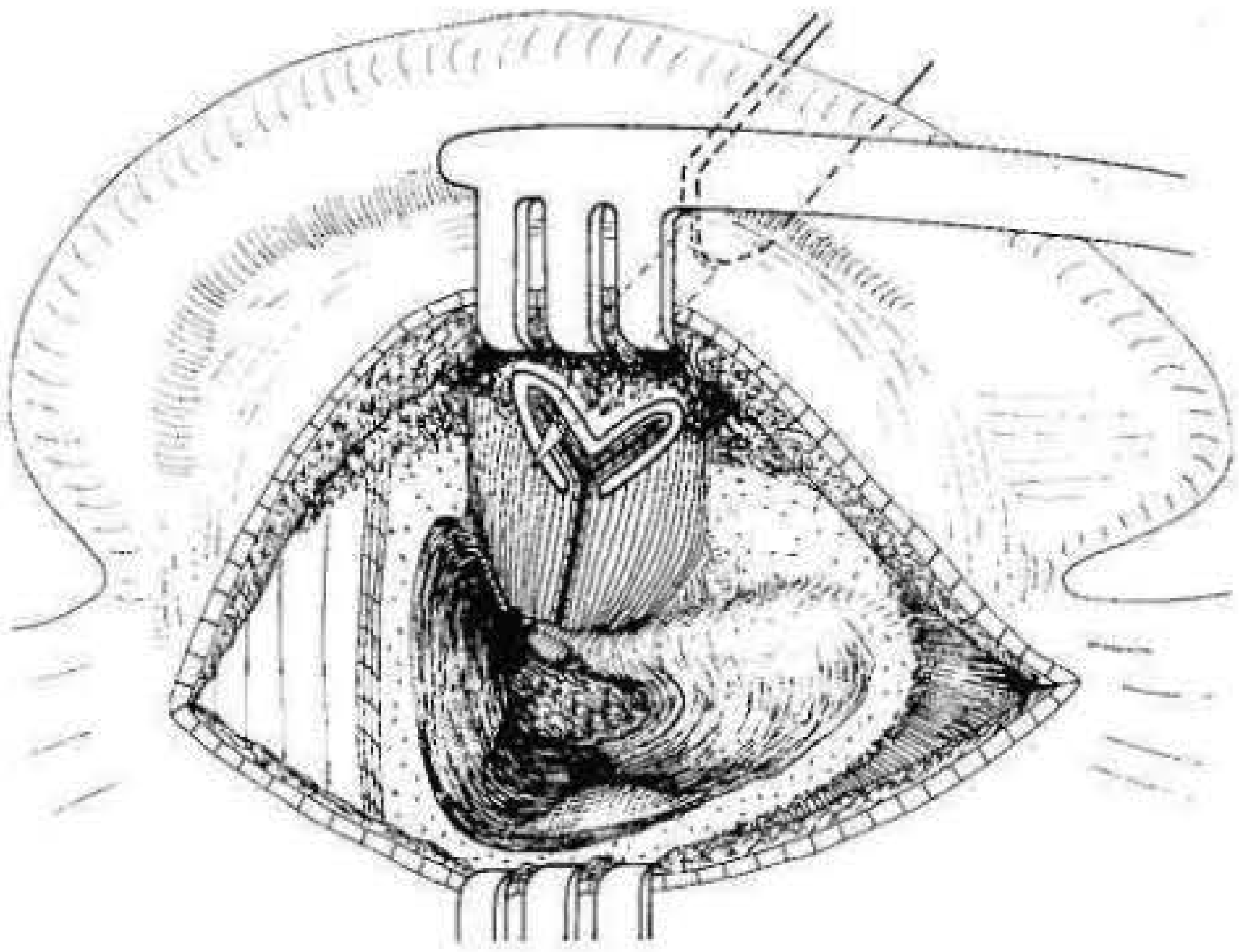


Fig. **764** **The Portmann large (five-flap) meatoplasty with removal of the cartilage.** First, a Y-shaped incision is made through the posterior ear canal skin, continuing into the cavum conchae. The incision here goes through the postauricular fibrous tissue, conchal cartilage, and the skin. The knife is placed through the ear canal

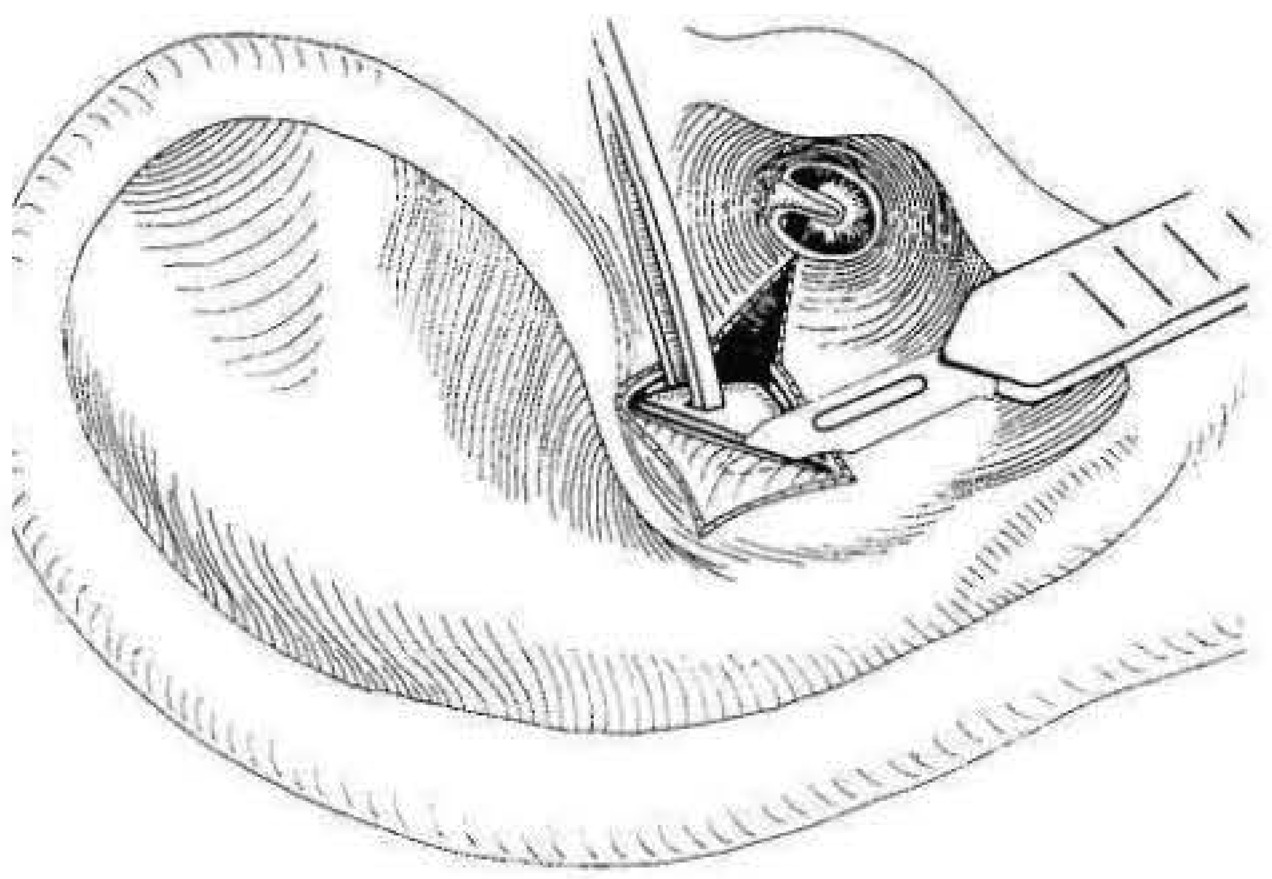


Fig. **765** The large Portmann meatoplasty seen from the anterior aspect, illustrating the Y-shaped incision. The skin from the laterally-based triangular conchal flap is elevated, exposing the conchal cartilage, which is resected using a knife

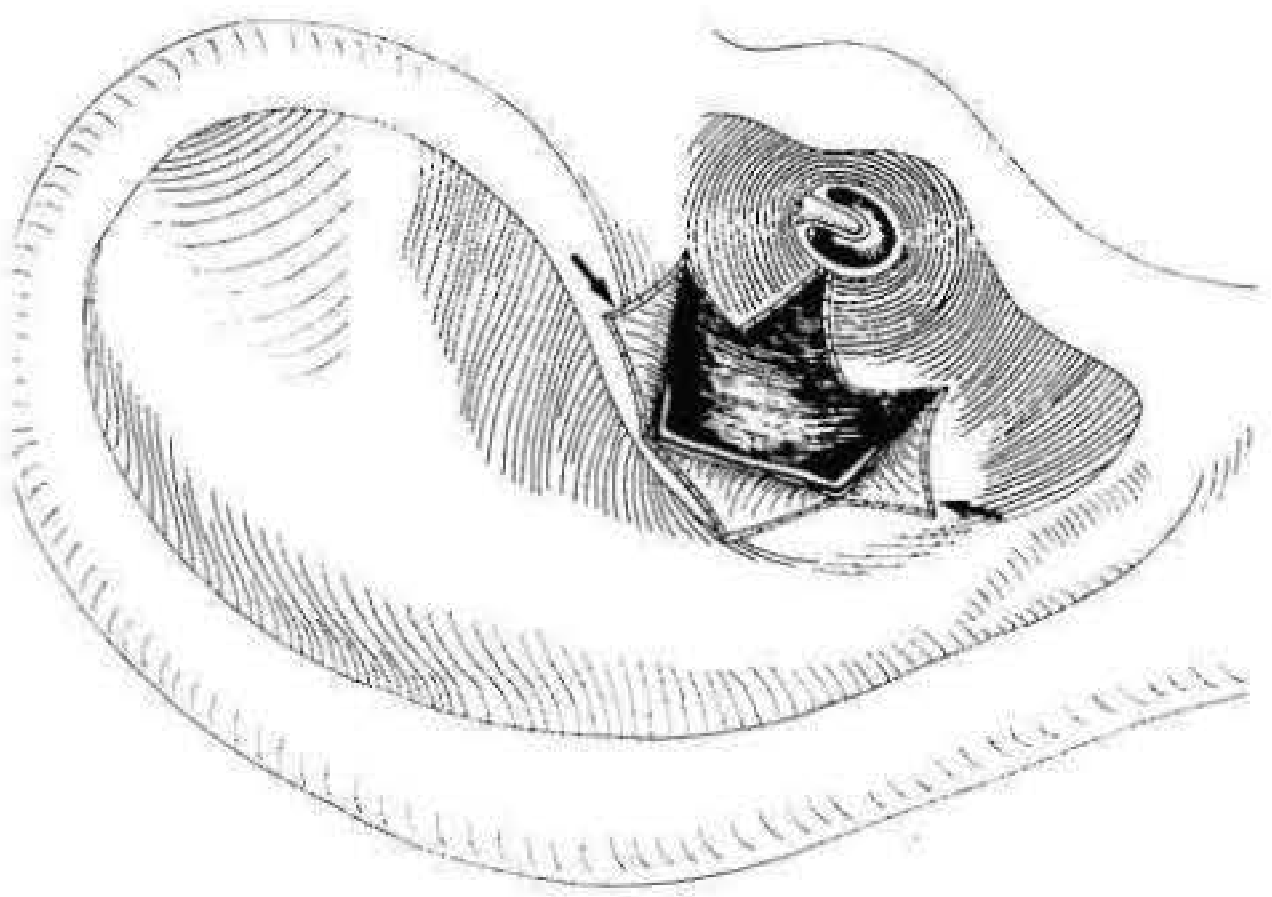
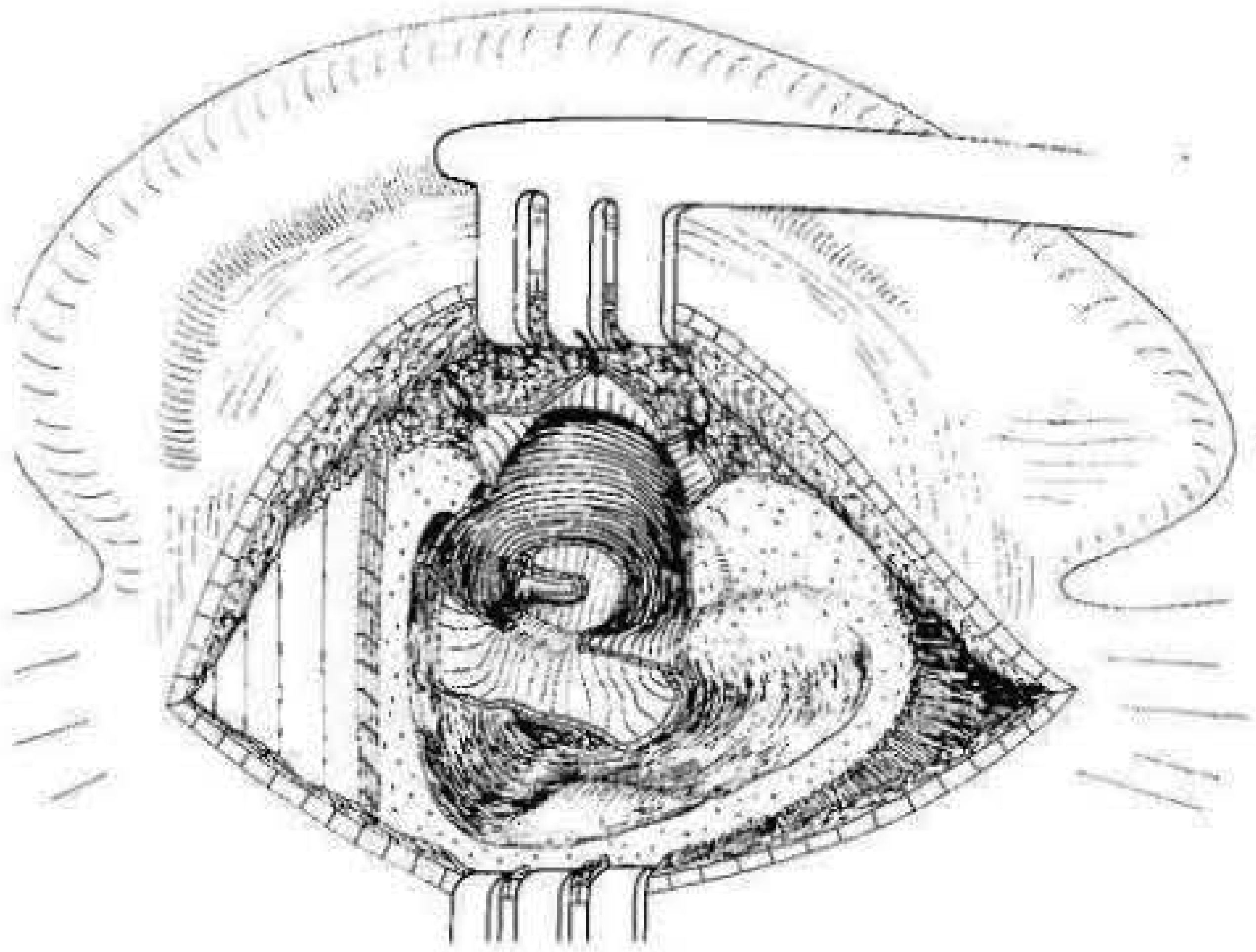


Fig. **767** The inferior part of the conchal cartilage is resected. The triangles of the skin between the meatal and conchal skin are resected both superiorly and inferiorly, giving the conchomeatal skin flaps (arrows) better mobility



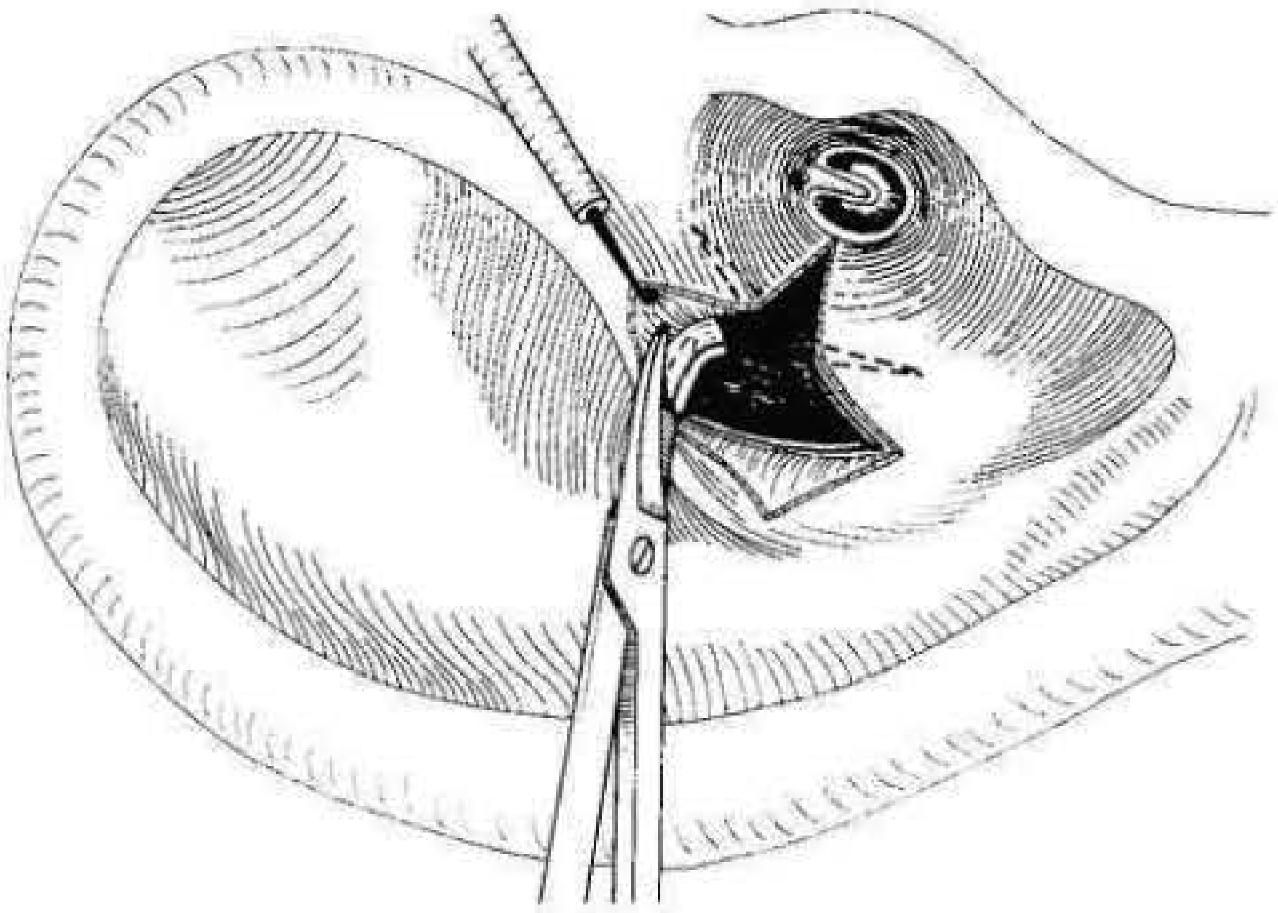


Fig. **766** The skin from the superior conchomeatal flap is elevated, and the upper part of the conchal cartilage is exposed and resected, as well as the anterior edge of the helix cartilage. Inferiorly and superiorly, the junctions between the skin of the concha and the meatal skin are indicated by dashed lines. These parts of the skin will be resected, giving the five skin flaps better mobility. The conchomeatal flaps can then be easily folded on the posterior aspect of the concha

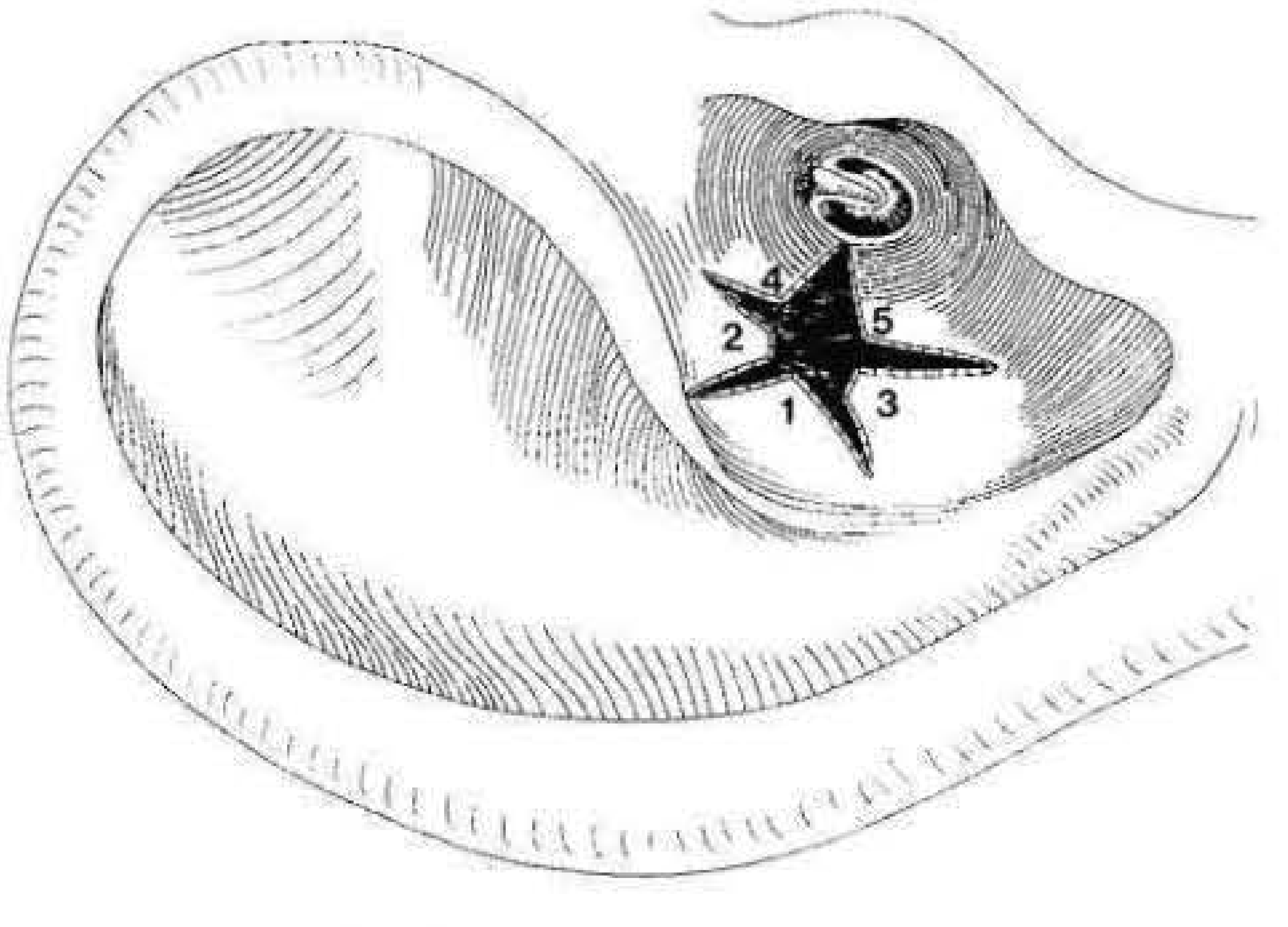


Fig. **768** The five flaps are now clearly visible in the anterior view: the laterally-based conchal flap (1), the superiorly-based conchomeatal flap (2), the inferiorly-based conchomeatal flap (3), the superior meatal flap (4), and the inferior meatal flap (5)

◁ Fig. **769** The skin flaps have been trimmed for subcutaneous tissue and inverted on the posterior aspect of the remaining conchal cartilage. They are fixed with catgut sutures. The tympanic cavity is reconstructed with a large piece of fascia as an underlay graft, also covering the medial wall of the attic and aditus. The inferior and superior meatal flaps are replaced, and will be fixed into their proper positions with Gelfoam balls or gauze placed through the ear canal into superior and inferior flaps. A small incision across the edge of the cavum conchae acts as a relieving incision for the inferior flap (Fig. **771**). The cartilage is resected from the retroauricular aspect, and the skin flaps are thinned. The superior and inferior flaps are inverted onto the posterior aspect of the remaining conchal cartilage, thus enlarging the ear canal.

The Fisch Meatoplasty. Fisch (1980, 1994) uses one anteroposterior incision (Fig. **772**), and elevates the skin flaps from the concha before resecting a major part of the conchal cartilage. The two liberated skin flaps are inverted posteriorly around the edge of the concha, and sutured to the posterior aspect of the concha (Fig. **773**).

Landolfi et al. 1983) uses an anteroposterior incision in the concha, like Fisch. The lateral meatal skin and the conchal skin, together with the perichondrium, is carefully elevated from the conchal cartilage, which is then exposed (Fig. **774**). Using a pair of scissors, the conchal cartilage is resected, including the anterior edge of the crus of the helix. A similar procedure is performed for the inferior conchal flap (Fig. **775**). The resection of the conchal cartilage enlarges access to the cavity, and the inverted flap of conchal skin provides the epithelial covering of the lateral wall of the cavity. In addition, Sanna uses part of the anterior canal wall skin as a superior flap (Fig. **776**).

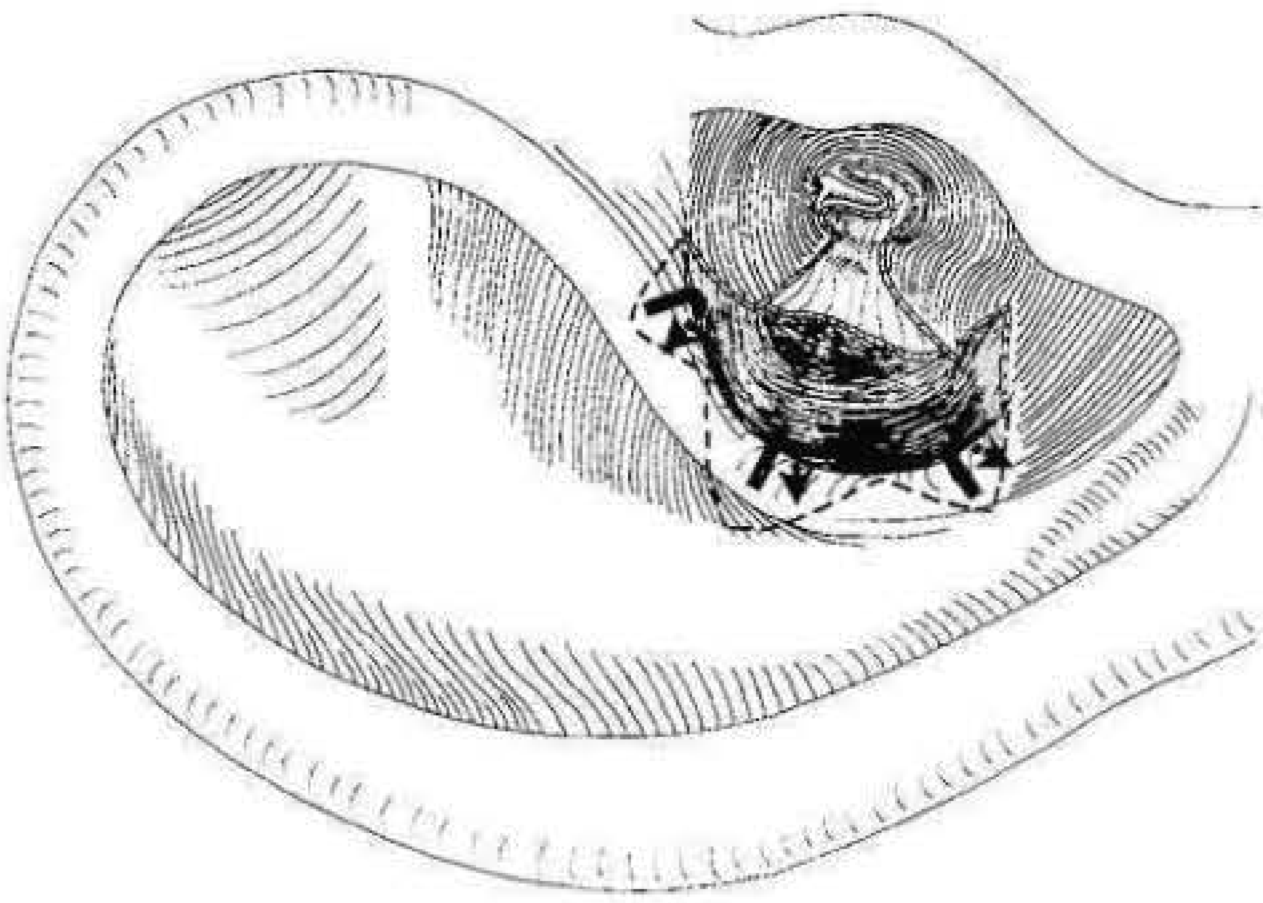


Fig. **770** The Portmann large meatoplasty, seen through the considerably enlarged ear canal. The dashed, lines and arrows indicate the positions of the fixed conchal skin flap (middle arrow) and superior and inferior conchomeatal skin flaps

The principle of all the meatoplasties described is to excise part of the conchal cartilage either anteriorly, with elevation of conchal skin flaps, or through the posterior aspect, with removal of fibrous tissue and excision of the conchal cartilage. The excision of cartilage anteriorly allows more accurate resection of the conchal cartilage, with the position of the

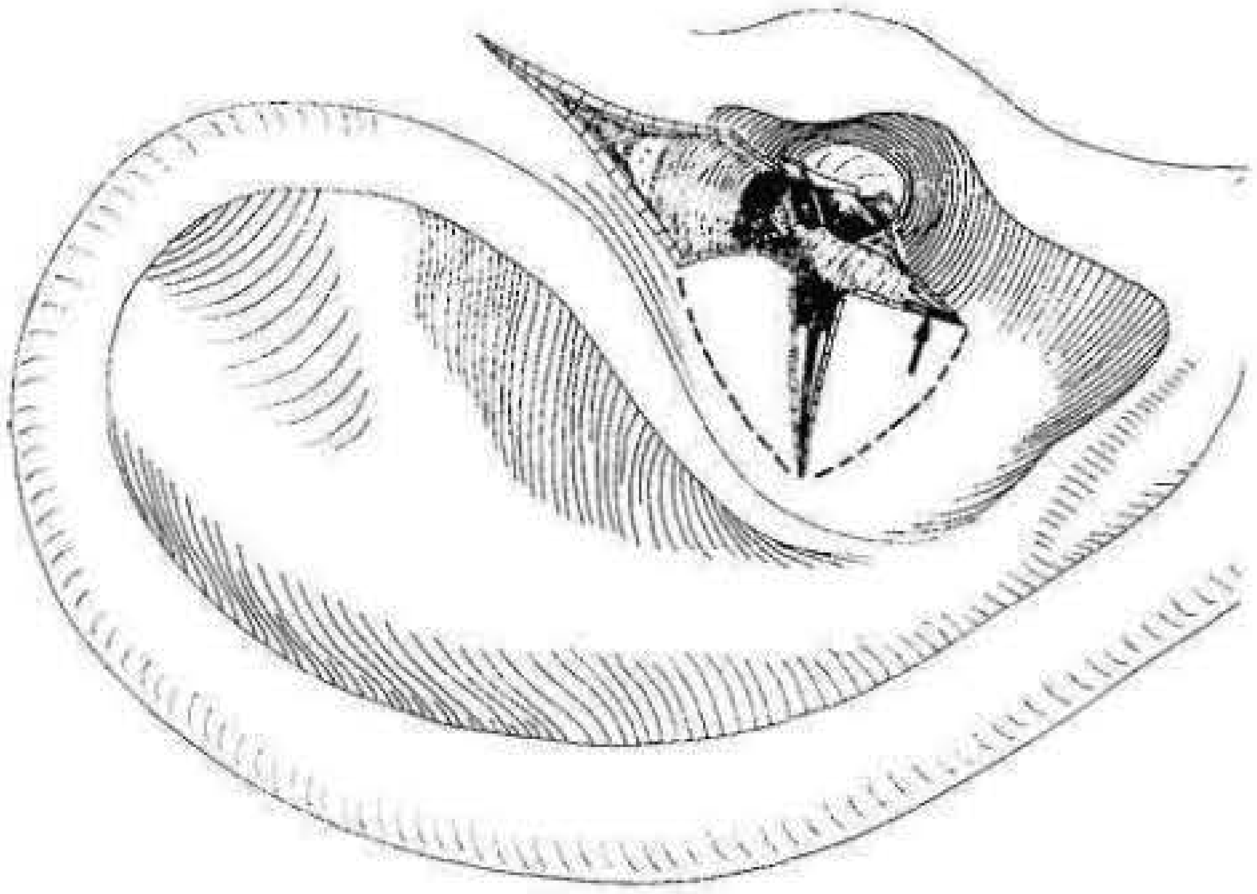


Fig. **771** **The Sheehy meatoplasty.** A vertical intercartilaginous incision is made at the 12-o'clock position, extending through the skin and subcutis down to the bone, and an incision is made at the 5-o'clock position into the conchal cartilage (arrow). A horizontal anteroposterior conchal incision at about the 9-o'clock position creates two conchomeatal flaps. Through the retroauricular approach, the conchal cartilage is exposed and excised, allowing folding of the flaps posterosuperiorly and fixation on the posterior aspect of the concha. Inferior to the conchal incision, the conchal cartilage is also removed. The extent of removal of the cartilage is indicated by the dashed line

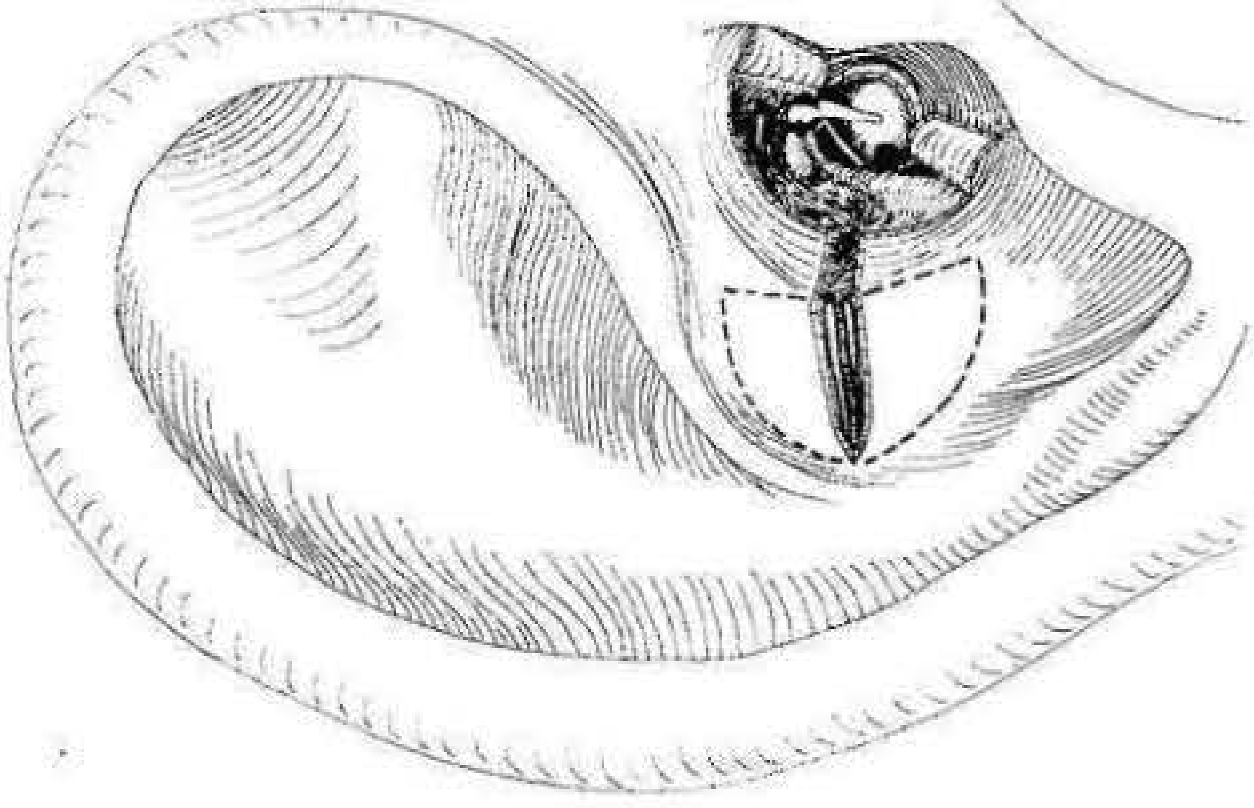


Fig. **772** **The Fisch meatoplasty** is performed with an incision into the concha through the skin, conchal cartilage, and fibrous tissue posterior to the concha. After elevation of the skin, the cartilage is removed to the extent indicated by the dashed line

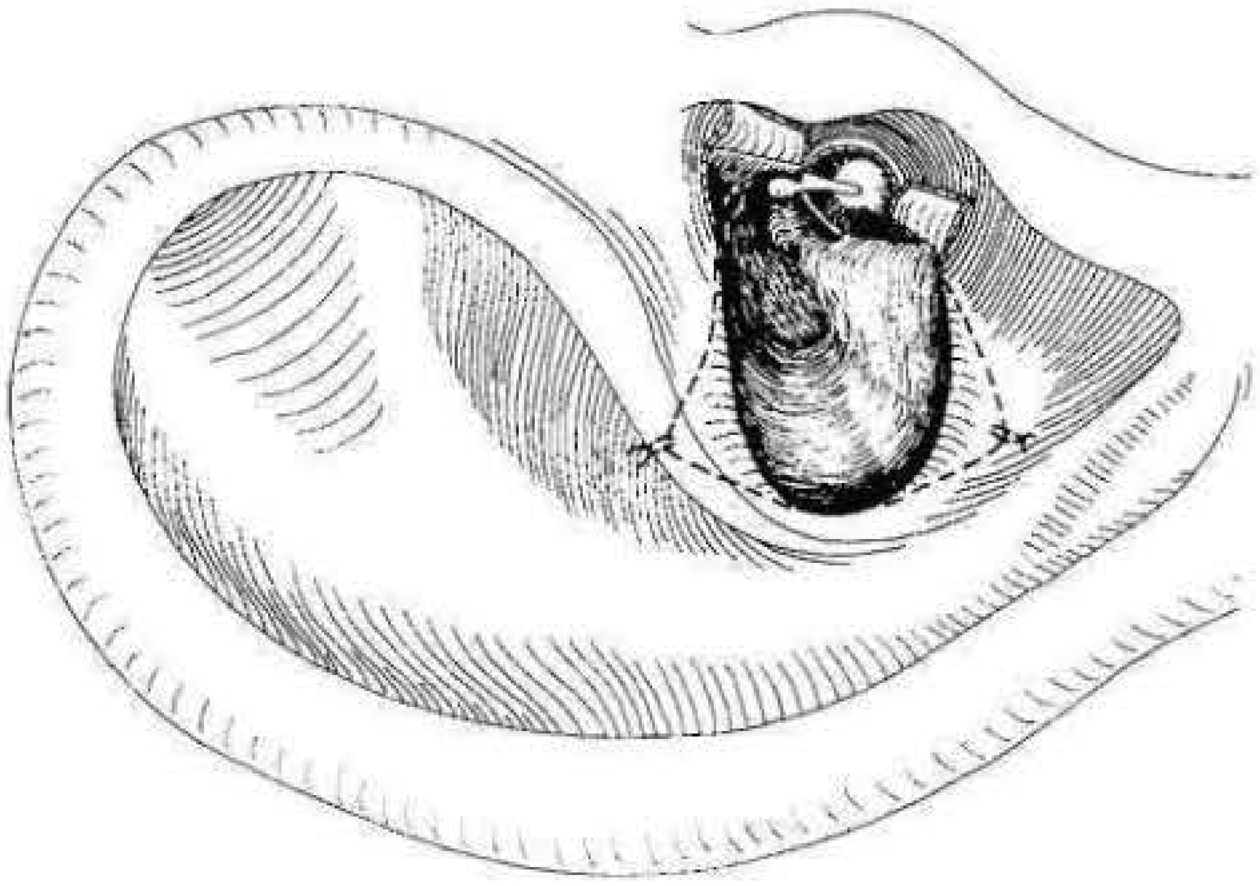


Fig. **773** The size of the ear canal in the Fisch meatoplasty. The conchal skin is folded around the edge of the cartilage and fixed to the posterior aspect of the concha with catgut sutures

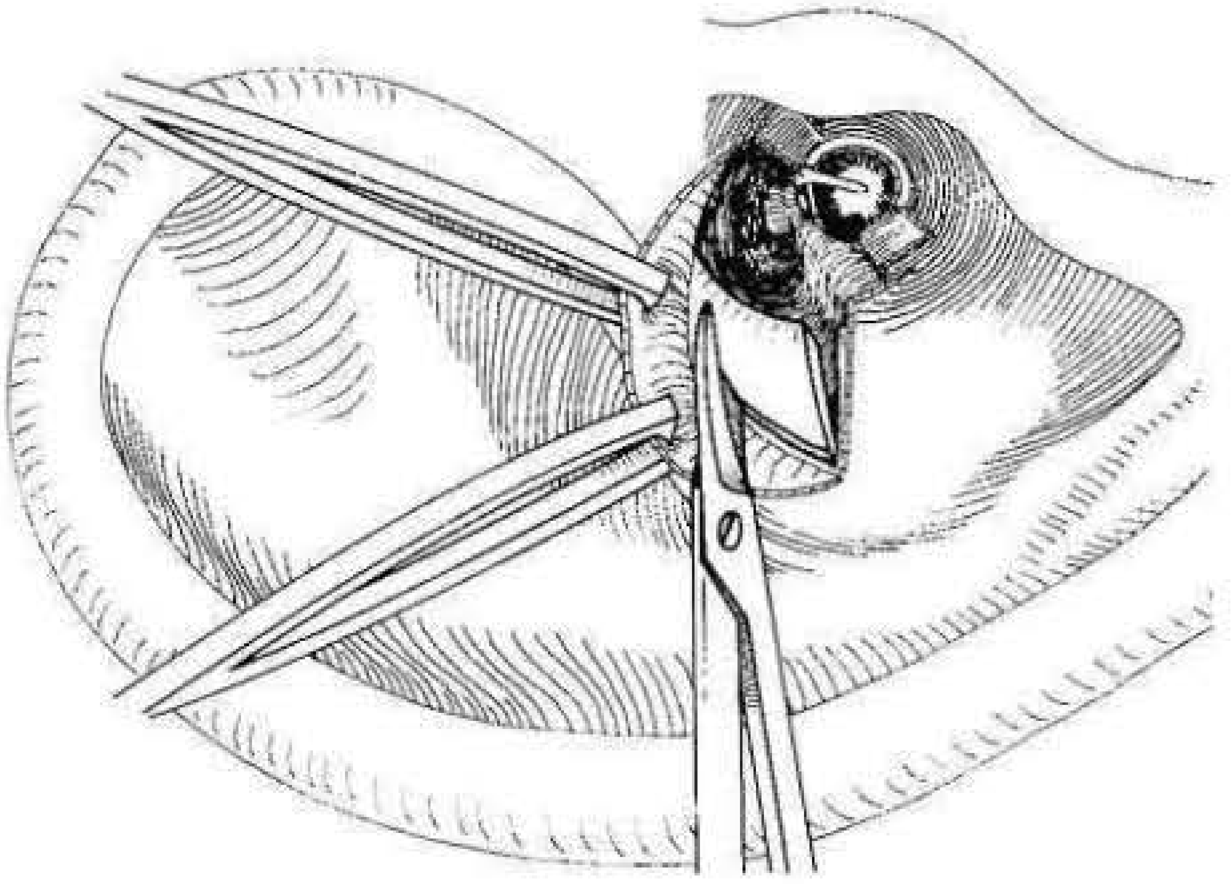


Fig. **774** **Modification of Fisch meatoplasty.** A conchal incision goes through the meatal skin and conchal cartilage. The conchal skin, with the perichondrium, is elevated from the superior part of the concha, exposing the conchal cartilage, which is excised with a pair of scissors

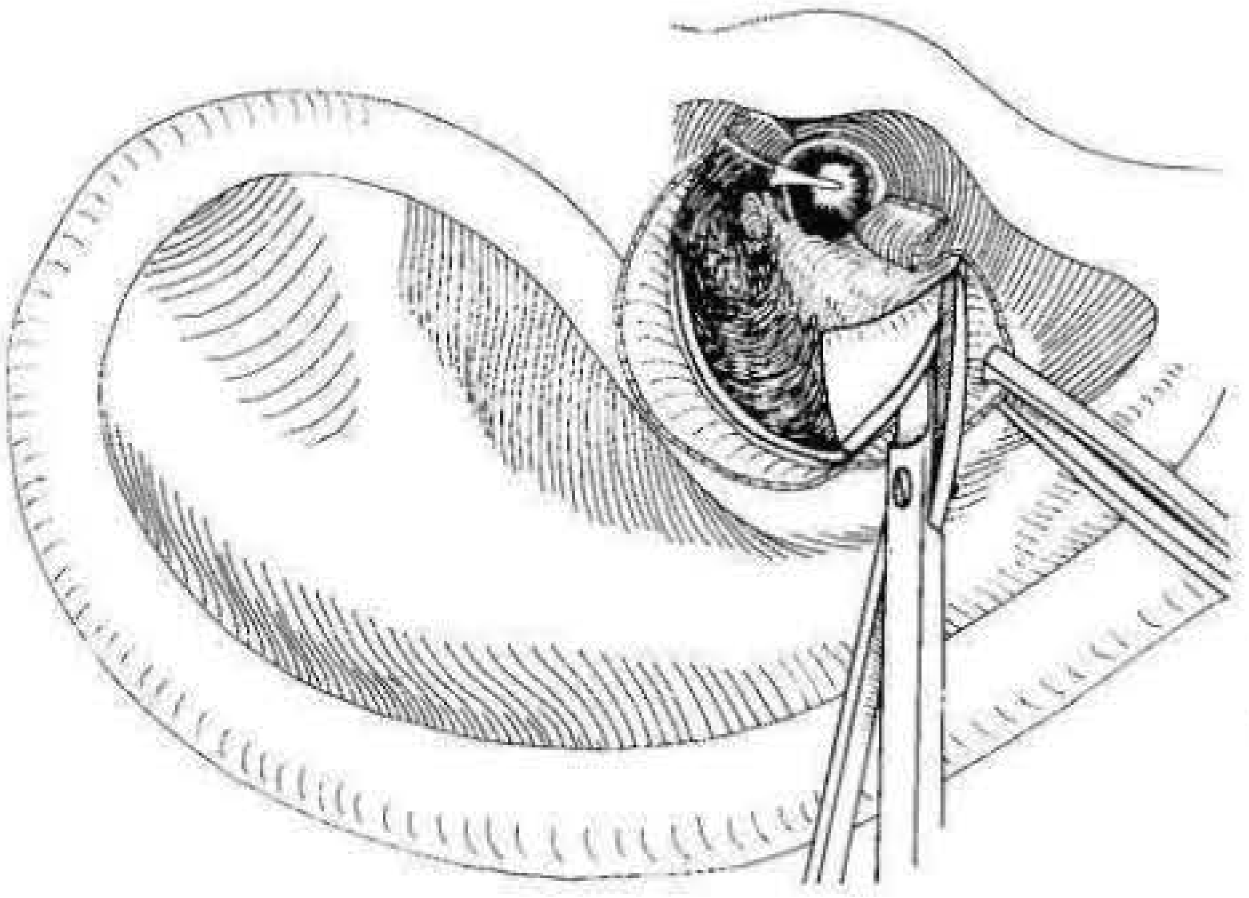


Fig. **775** The inferior part of the conchal cartilage is removed, and the skin flaps are folded around the edge of the concha

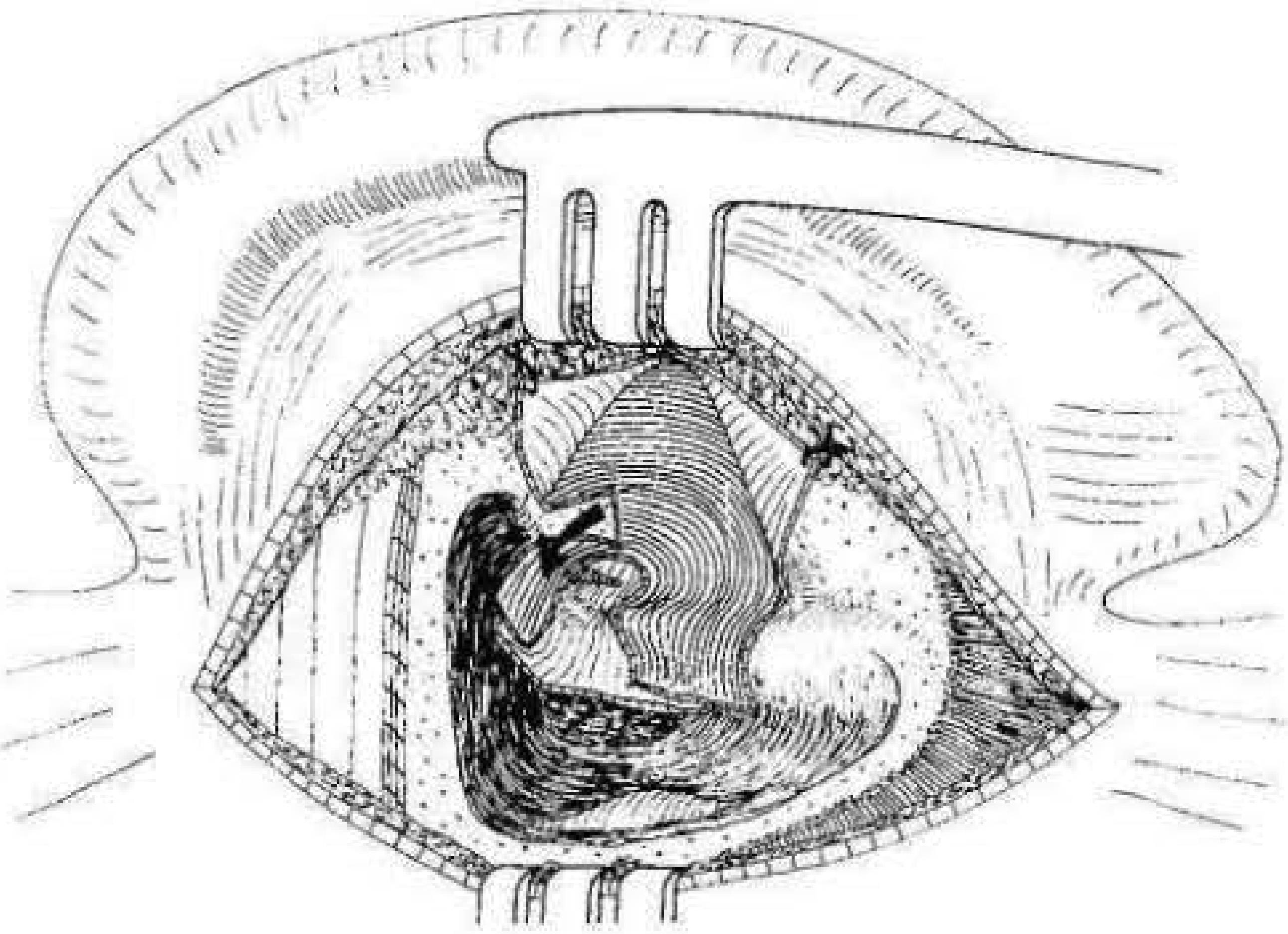


Fig. **776** The retroauricular view of the meatoplasty, with folded and fixed skin flaps. From the anterior aspect of the ear canal, the canal skin is elevated and transposed as a superior flap toward the superior wall of the cavity (arrow). The fascia covers the total perforation as an underlay graft

pinna and the size of the ear canal reedily visible, so that additional resection of the conchal cartilage is easily performed.

Some of the methods specifically avoid the problem of stiffness of the conchal skin, and its tendency to take up its original position even after resection of the concha. The skin has to be thinned, and often the flaps have to be sutured to the posterior aspect of the cavum conchae to ensure the correct positioning of the flaps and to allow for further epithelialization of the lateral wall of the cavity. One can debate which of the methods is better. Some of them are relatively easy to perform, while others are more complicated, particularly the Portmann five-flap technique, although the latter does not need firm postoperative packing. In other techniques, firm packing is essential. The variety of meatoplasties available makes it possible to achieve a sufficiently large external meatus in any situation.

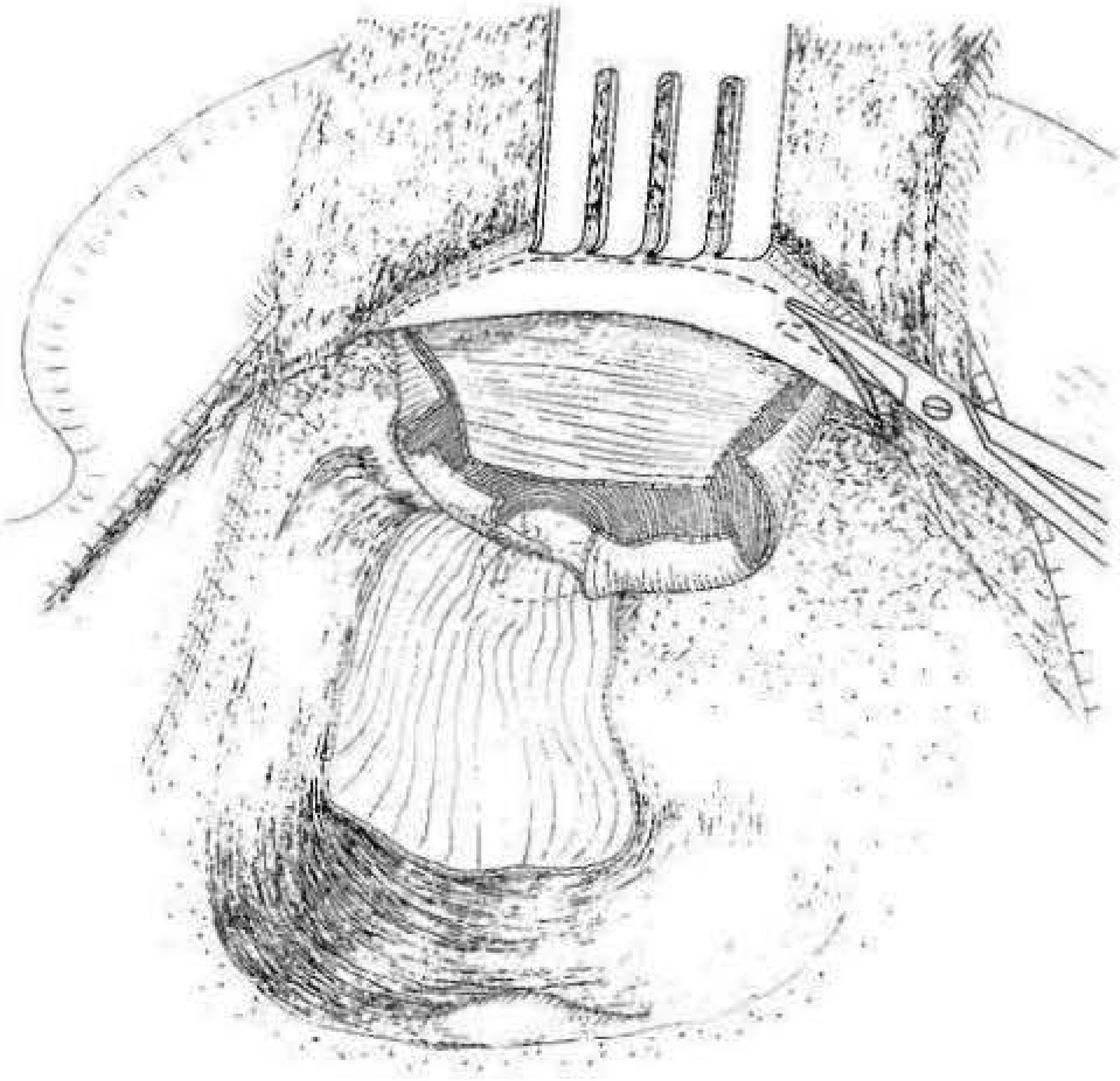
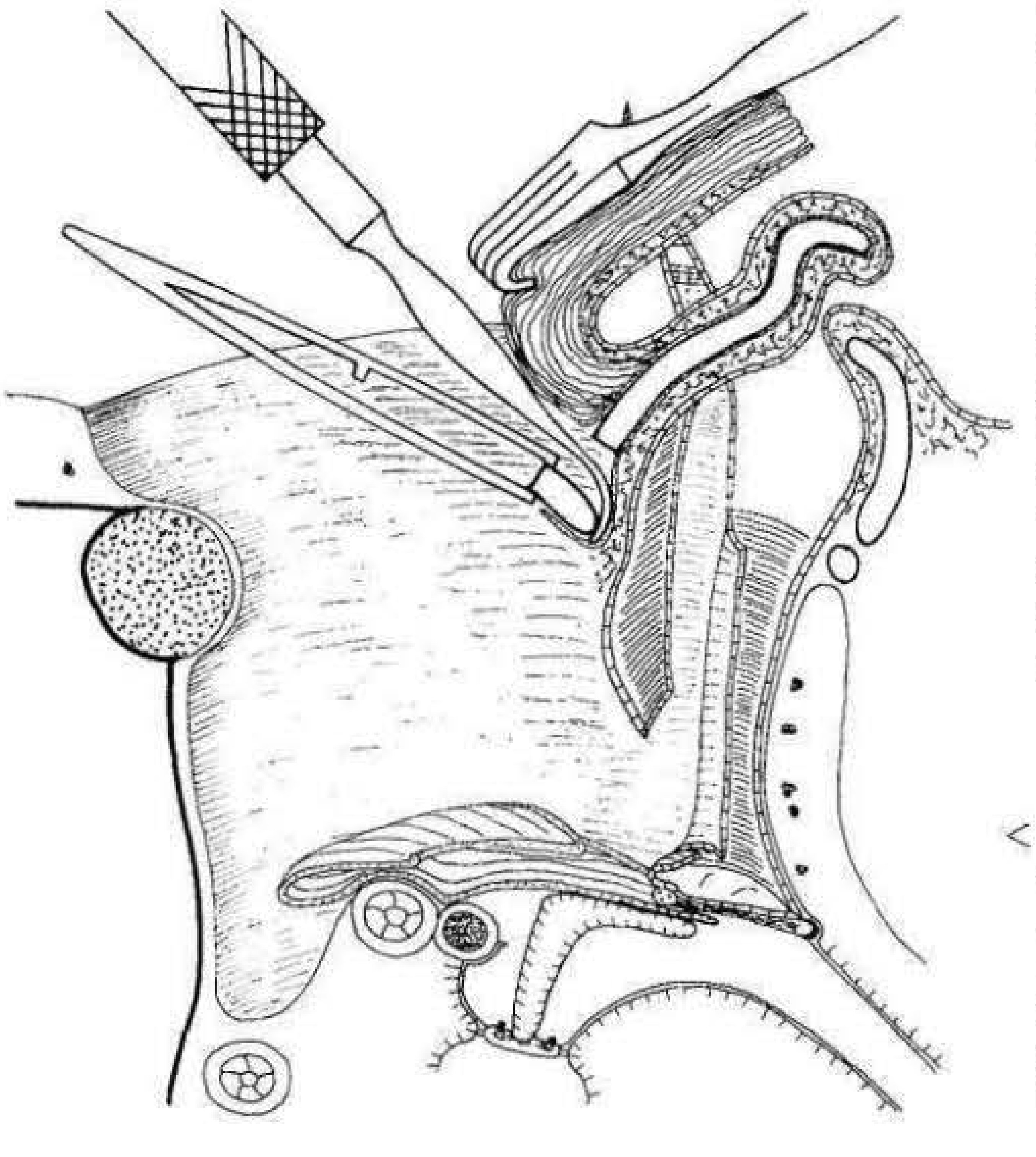


Fig. **777** **Retroauricular meatoplasty and cavity obliteration with a Palva flap.** A canal wall–down mastoidectomy is performed, a columella is placed between the footplate and the malleus handle, and the posterior perforation is covered with an underlay fascia graft, extending over the medial wall of the cavity. Laterally, a large Palva flap has been raised. Under the flap, the perichondrium is incised, and the medial edge of the conchal cartilage is exposed. A 5-mm strip of the most medial part of the conchal cartilage is excised using a pair of scissors. The perichondrium is left in place to support the Palva flap. Laterally, a Körner flap is enlarged



< Fig. **778** Side view of the subperichondrial removal of the medial part of the conchal cartilage. The Palva flap is elevated and held away, exposing the medial edge of the cartilage, which is resected subperichondrally and will be removed. The cavity is ready to be obliterated. Ossiculoplasty is performed, and the drum and the medial cavity wall are covered with fascia

Meatoplasty and Obliteration

After canal wall–down mastoidectomy and obliteration of the cavity, a widening of the ear canal, or a meatoplasty and resection of the conchal cartilage, is often performed (Figs. **722, 723**).

Widening of the ear canal *without* resection of the conchal cartilage by using the intercartilaginous incision at the 12-o'clock position with some cranial extension, or possibly an additional incision through the cartilage at the 6-o'clock position (Fig. **750**), does not interfere with any obliteration technique.

Meatoplasty *with* resection of conchal cartilage does interfere with the most commonly used obliteration, using the Palva flap. This subcutis–muscle flap is based anteriorly at the conchal cartilage, which has to be resected. The flap may lose its attachment and its vascular supply, but the present author has used the following two subperichondral techniques to resect the conchal cartilage with the Palva flap in situ.

Subperichondral resection in a posterior approach. At the end of the operation, after a myringoplasty has been performed and the Palva flap has been elevated, an incision is made through the perichondrium of the lower edge of the conchal cartilage (Fig. 777). The perichondrium is elevated, together with the attached Palva flap, exposing the posterior aspect of the conchal cartilage. Using a pair of scissors, a strip of about 5 mm of conchal cartilage is resected without disturbing the flap (Fig. **778**). The subcutis–muscle flap obliterates the posterior part of the cavity, which remains mainly as an open cavity, with a widened ear canal and meatoplasty (Fig. **779**).

Transmeatal subperichondral resection of conchal cartilage. In order to avoid surgery at the attachment of the Palva flap from the retroauricular aspect, the conchal cartilage can be resected transmeatally (Fig. **780**). An intercartilaginous incision at the 12-o'clock position is made, and extended cranially anterior to the helix. An incision through the skin and the cartilage at the 5-o'clock position is made. The skin is carefully elevated together with the perichondrium (Fig. **781**). The medial edge of the conchal cartilage is exposed, and a strip is

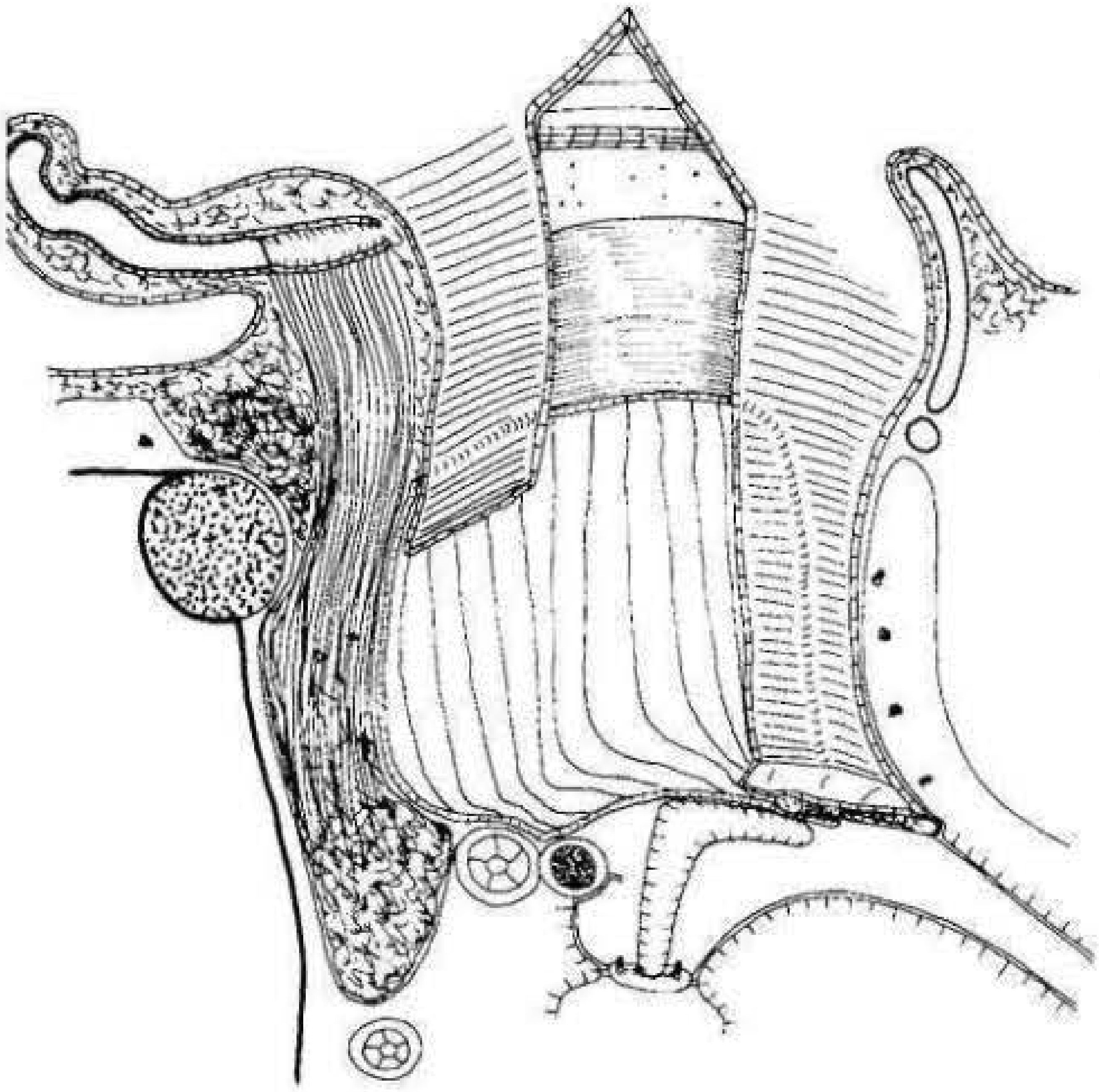


Fig. **779** The Palva flap covers the posterior cavity wall. The remaining cavity is open and partly covered with a piece of fascia, extending over the Palva flap. Posterolaterally, a Körner flap covers the subcutis–muscle flap

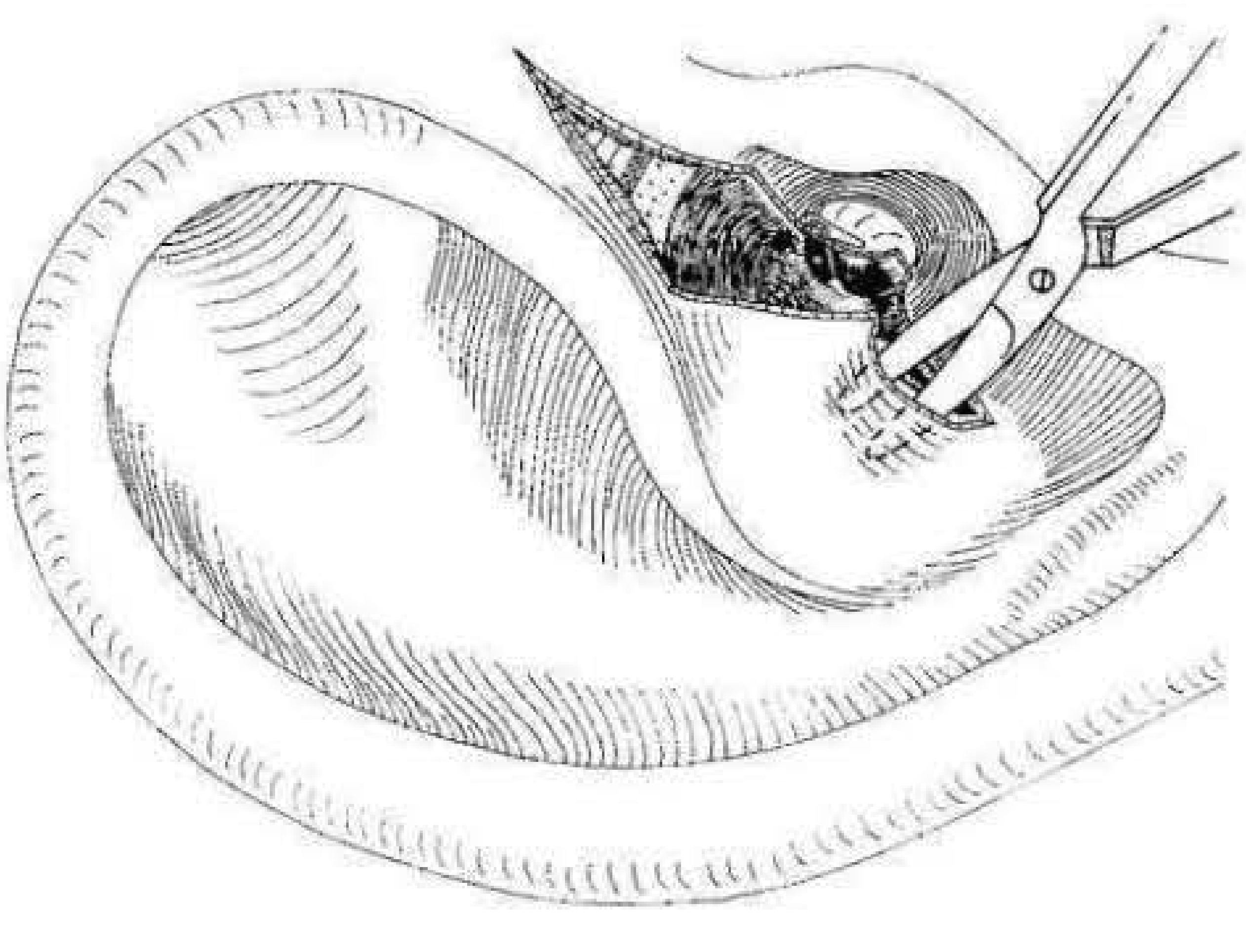


Fig. **780** **Transmeatal resection of conchal cartilage in a situation with canal wall down mastoidectomy and a Palva flap. The** ear canal is widened with an intercartilaginous incision at the 12-o'clock position and an incision through the conchal cartilage at the 5-o'clock position. Using a pair of scissors, the conchal skin and the meatal aspect of the perichondrium are elevated from the medial part of the conchal cartilage

resected, leaving the perichondrium intact. The Körner flap is further elevated in order to be placed on the posterior aspect of the cavity later (Fig. **782**). Removing part of the conchal cartilage in the endaural approach means that the attachment and vascular supply of the Palva flap are not disturbed essentially, and the cavity can be obliterated and reconstructed (Fig. **783**).

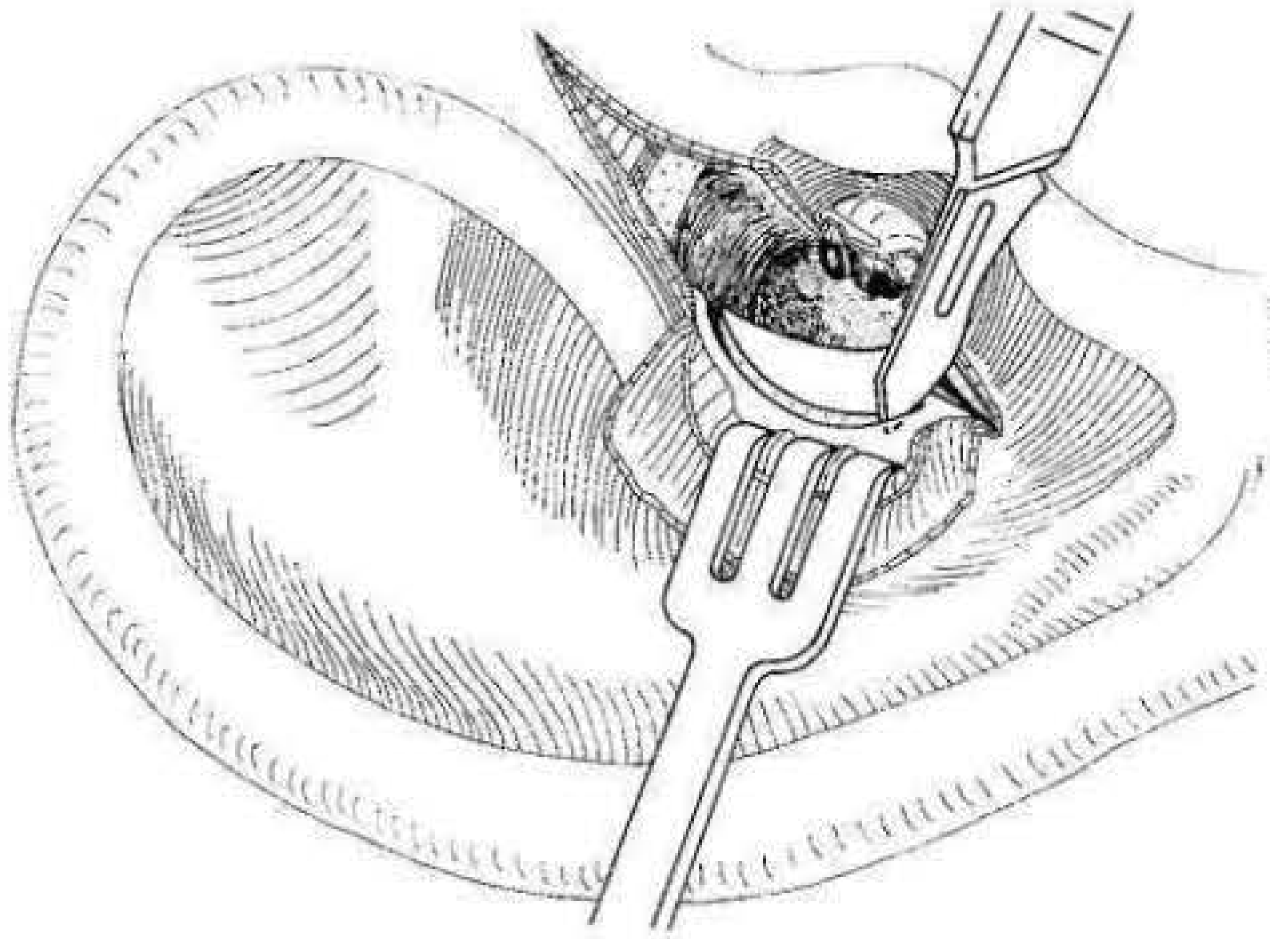


Fig. **781** The conchal skin and the perichondrium are elevated, exposing the medial edge of the conchal cartilage. The cartilage is resected using a scalpel

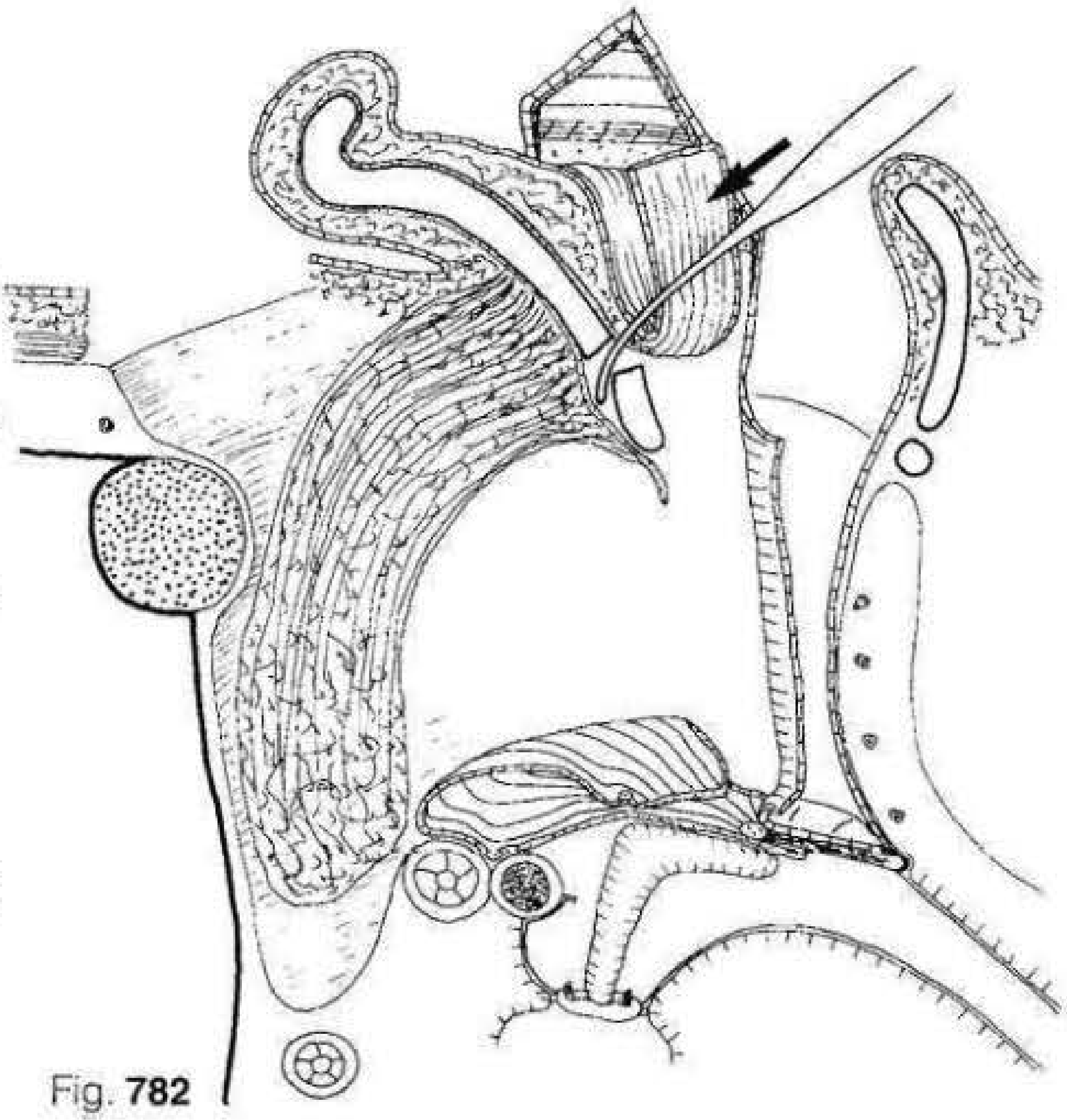


Fig. **782** Side view of the transmeatal removal of conchal cartilage in a situation with canal wall–down mastoidectomy and a Palva flap. The conchal skin is elevated, forming a Körner flap (arrow). The conchal cartilage is elevated subperichondrally, preserving attachment of the Palva flap to the remaining conchal cartilage and the perichondrium

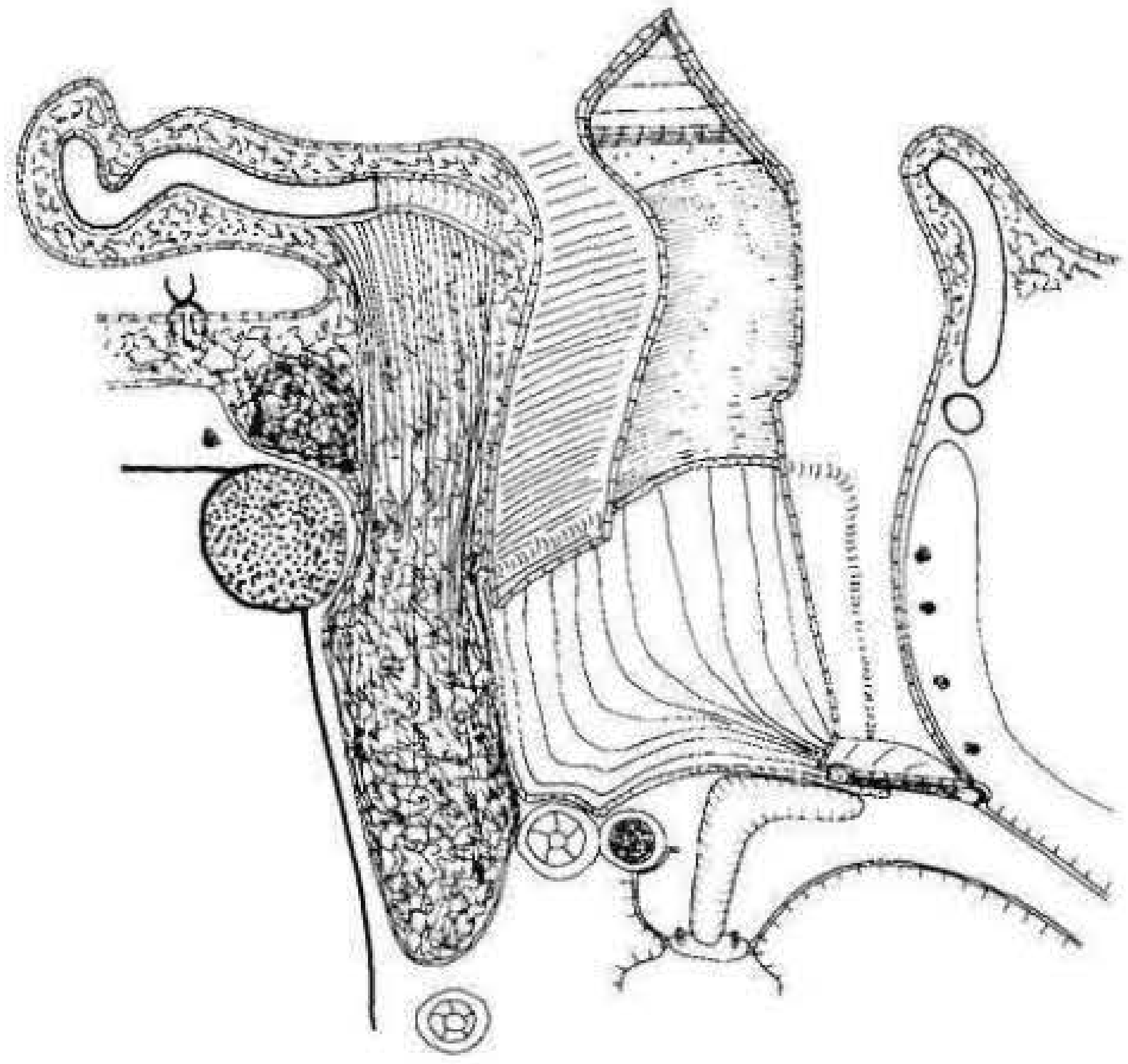


Fig. **783** The Palva flap is in situ, and the fascia covers the drum perforation, the columella, the medial cavity wall, and the subcutis–muscle flap. The Körner flap covers the lateral part of the cavity. The ear canal is widened, and the medial part of the conchal cartilage is resected

Modification of the Palva flap and Meatoplasty

In order to perform meatoplasty and obliteration, the Palva flap can be modified at the beginning of the operation (Teig 1994). The advantage of this technique is that meatoplasty is performed at the beginning of the operation, allowing good access to the ear canal. After a retroauricular incision, the skin is elevated, and a curved incision is made through the subcutaneous tissue and the periosteum to elevate a large Palva flap (Fig. **784**). Before elevating this flap, another incision is made along the entrance of the ear canal, extending from the 12-o'clock to the 6-o'clock positions through the subcutaneous tissue, muscle, and periosteum (Fig. **784**). After this incision, the Palva flap loses its anterior attachment to the pinna. It is only attached superiorly and inferiorly, and is held in place during the surgery. A strip of gauze is placed in the ear canal, extending it so that the lateral circumferential incision of the ear canal skin at the level of the suprameatal spine between the 12-o'clock and 6-o'clock positions does not damage the skin on the opposite site of the ear canal (Fig. **785**). The ear canal is now open, and a meatoplasty is performed by turning the pinna backwards, making an intercartilaginous incision at the 12-o'clock position and an incision through the conchal cartilage at the 5-

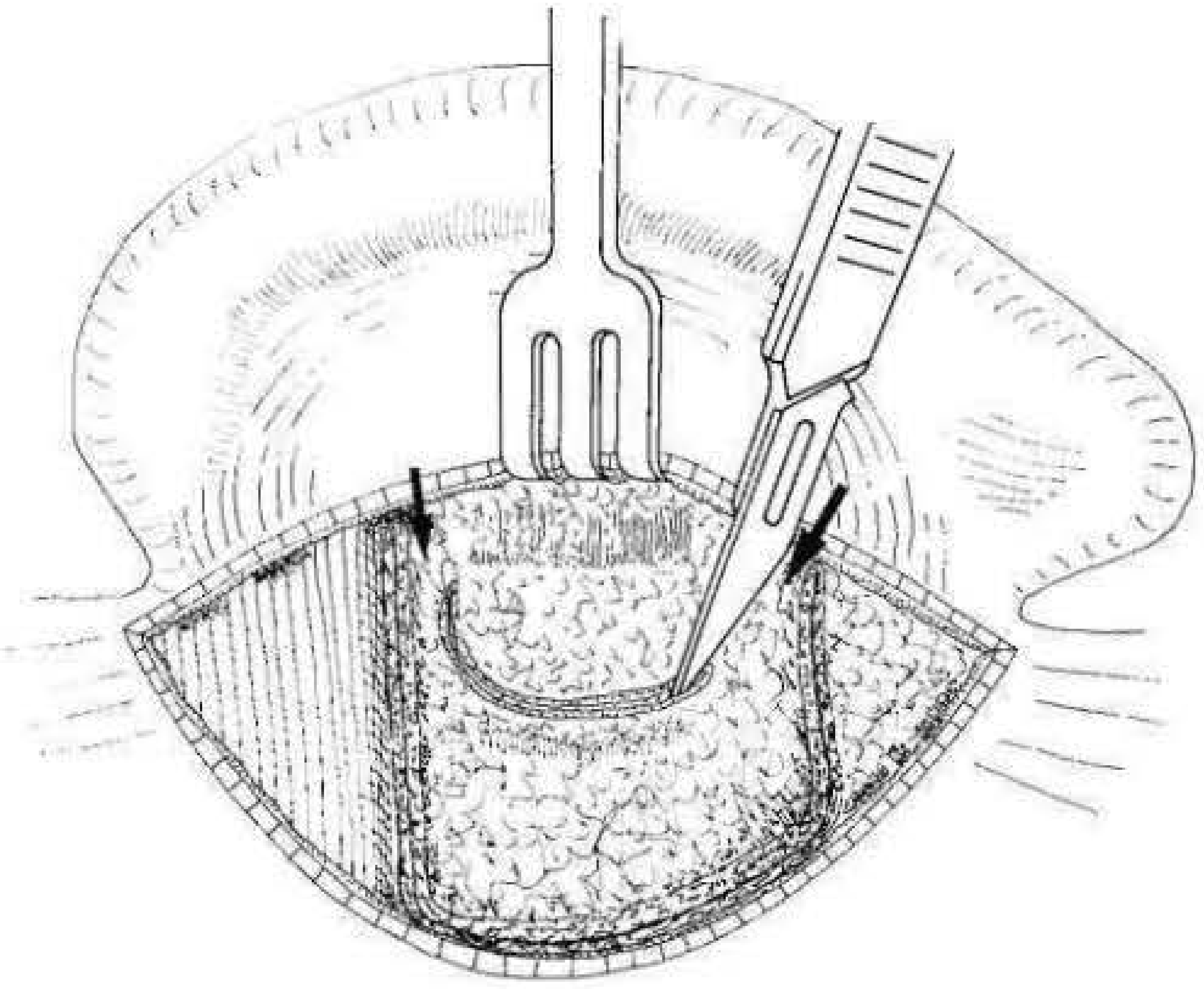


Fig. **784** **Meatoplasty and cavity obliteration with a modified Palva flap.** In a retroauricular approach, the skin is elevated. The subcutis and periosteum are incised along the temporalis muscle, and then posteriorly and inferiorly in order to be able to elevate a large Palva flap. The subcutis and periosteum are further incised between the 12-o'ciock and 6-o'clock positions along the entrance of the ear canal, thus modifying the Palva flap and allowing vascular supply to the flap superoanteriorly and inferoanteriorly (arrows)

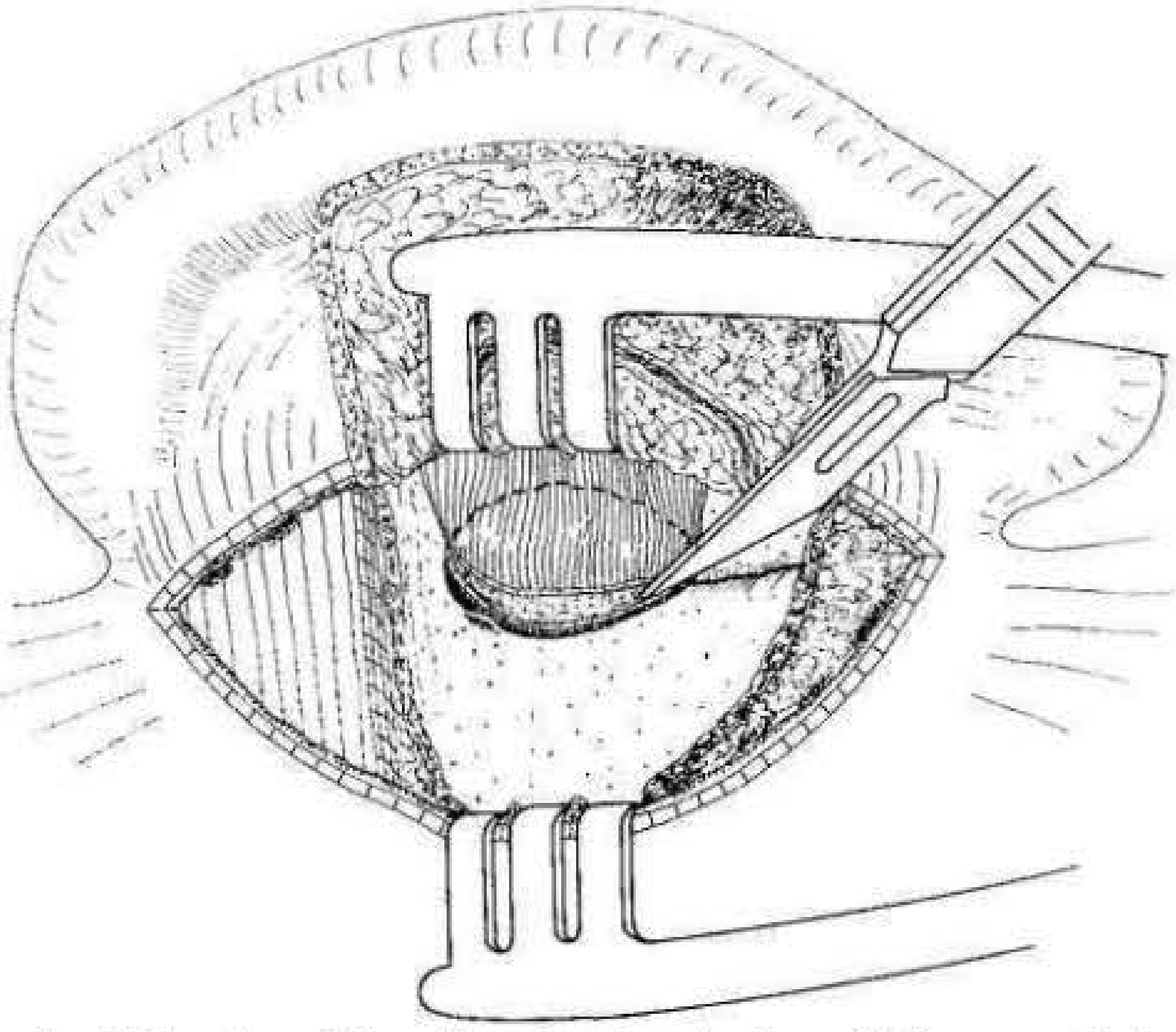


Fig. **785** The Palva flap is elevated, and the mastoid plane is exposed. A strip of gauze is placed in the external meatus, protecting the anterior ear canal skin. A lateral circumferential incision is made at the level of the suprameatal spine, between the 12-o'clock and 6-o'clock positions, exposing the gauze o'clock position (Fig. **786**). The auricle is again pulled forwards, the conchal cartilage is exposed, and a large strip of cartilage is excised (Fig. **787**). The Körner flap is turned around the resected concha and the Palva flap is elevated and fixed using a selfretaining retractor (Fig. **788**).

A radial incision is made at the 9-o'clock position through the ear canal skin, elevating an inferior and superior canal skin flap, and a canal wall–down mastoidectomy is then performed (Fig. **788**). The modified Palva flap is now placed in the cavity, attached only superoanteriorly and inferoanteriorly (Fig. **789**). It is stretched, and obliterates mainly the posterior part of the cavity and the sinodural angle (Fig. **790**). Most of the cavity will be an open cavity covered with fascia, with a wide ear canal (Fig. **791**). This type of open cavity has a good chance of rapid epithehalization, and the cavity lining seems to be solid, with good migration properties.

The Palva flap can be cut in the middle, thus creating two subcutis–muscle flaps, one attached

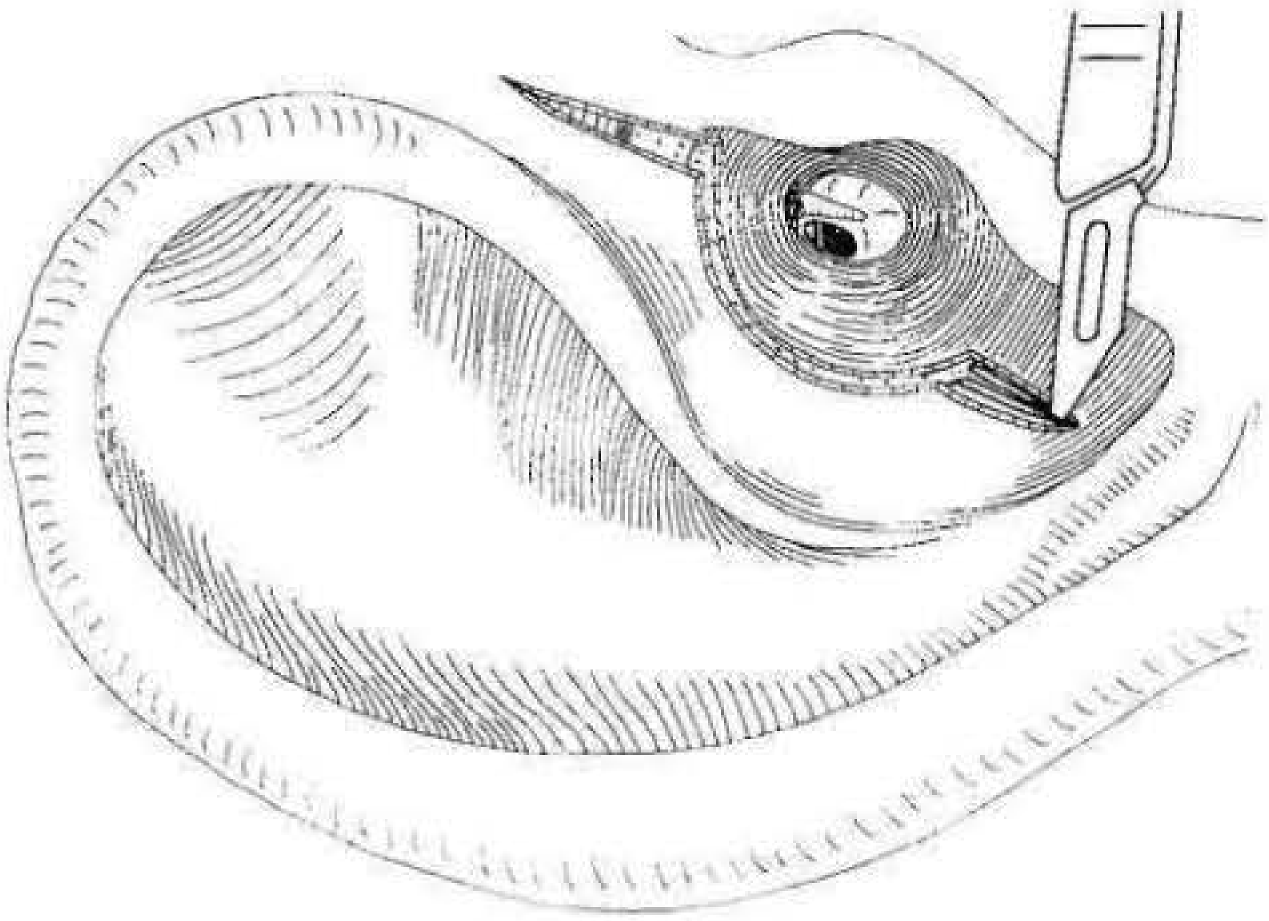


Fig. **786** **Transcanal meatoplasty incisions.** An intercartilaginous incision is made at the 12-o'clock position, extending 1–2 cm cranially, and an incision is made through the conchal skin and cartilage, at the 5-o'clock position

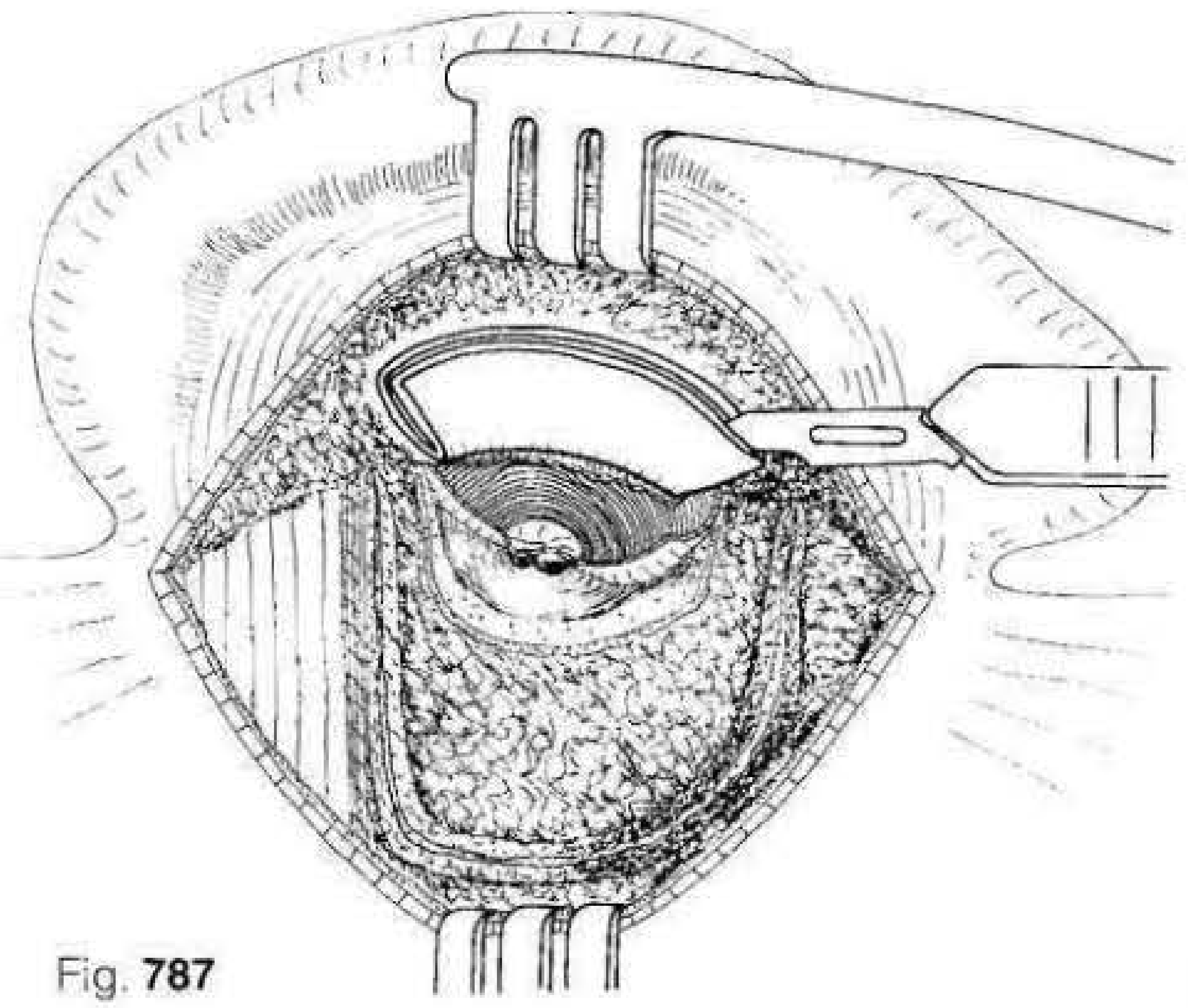


Fig. **787**

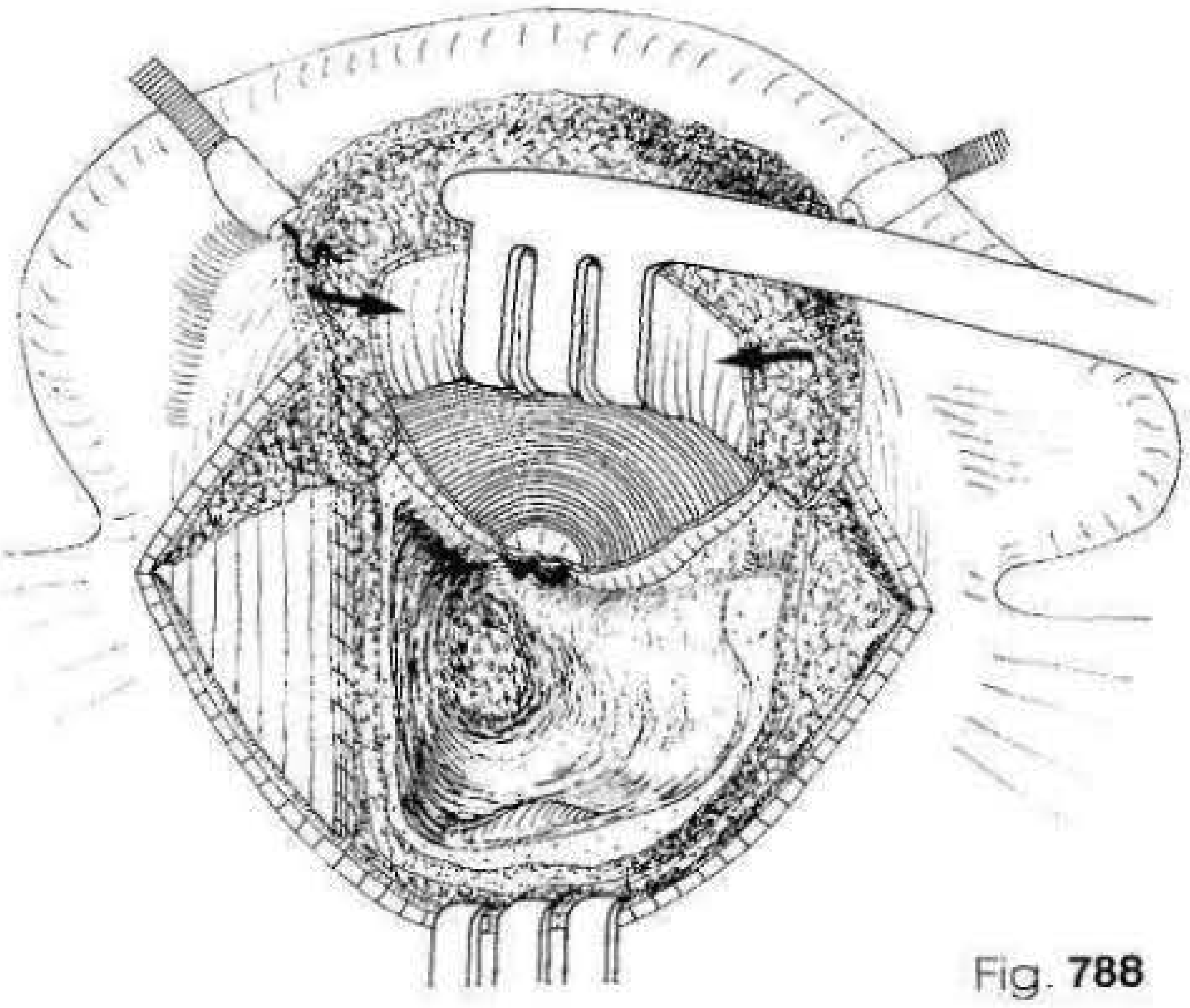


Fig. **788**

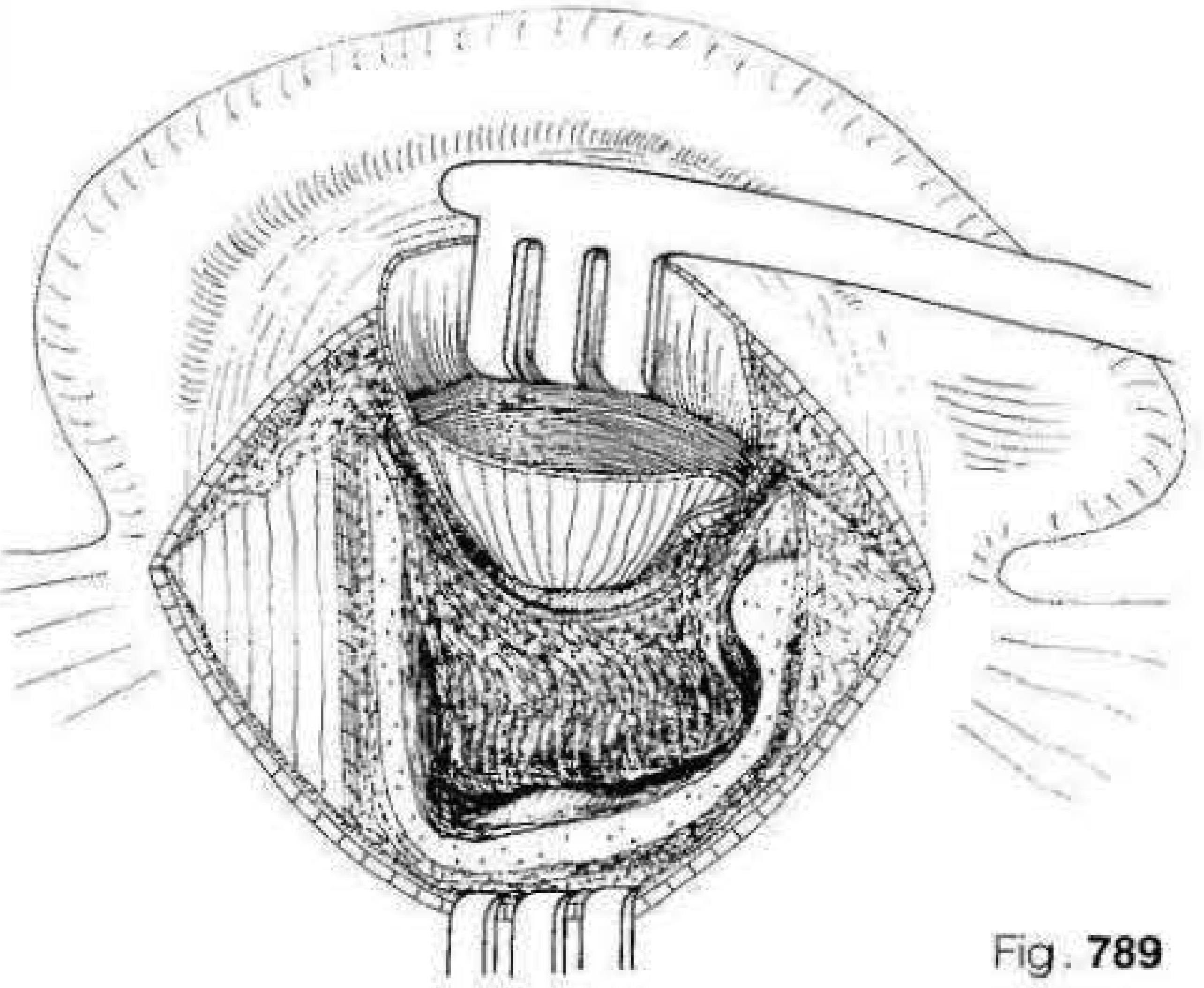


Fig. **789**

Fig. **787** The pinna is turned forward, and the conchal cartilage is exposed and resected using a scalpel. The conchal cartilage will be removed, enlarging the meatus. Within the bony ear canal, a radial incision is made at the 9-o'clock position, through the canal skin, and the superior and inferior canal skin flaps are elevated

Fig. **788** The Palva flap is again elevated, as is the Körner flap, which is turned around the resected conchal cartilage (arrows). A canal wall–down mastoidectomy is performed

Fig. **789** The modified Palva flap is placed in the cavity. It is based superoanteriorly and inferoanteriorly. A piece of fascia is placed under the drum remnant and the ear canal skin flaps superoanteriorly and the other inferoanteriorly (Fig. **792**). The subcutis–muscle flaps are adapted to the cavity walls, obliterating the cavity only partly. The fascia covers the medial wall of the cavity, which remains open (Fig. **793**). Using this modification of the Palva flap, a large meatoplasty can be performed, with rapid epithelialization of the cavity.

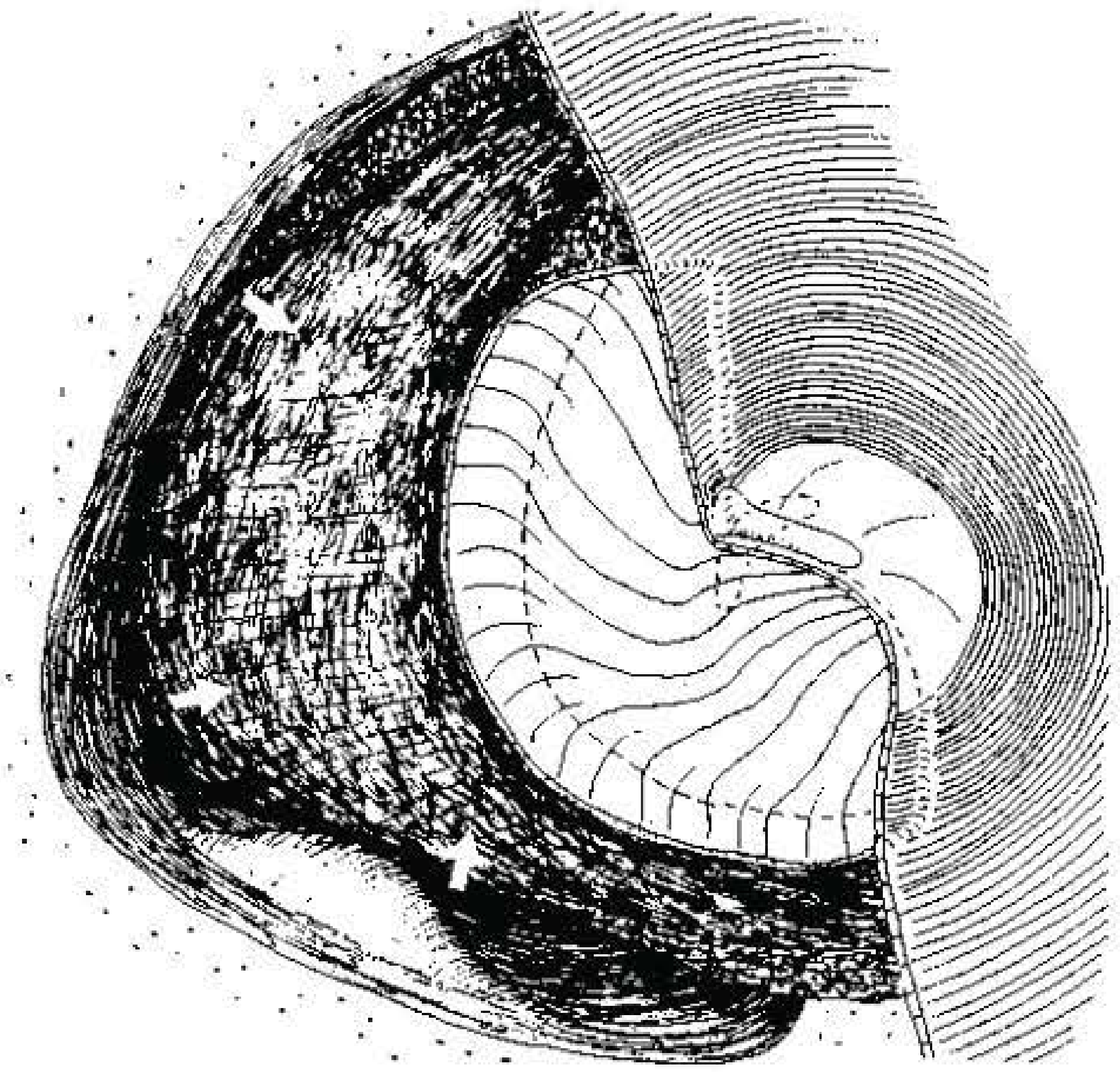


Fig. **790** The ossiculoplasty is performed using a columella. The fascia graft covers the medial wall of the cavity and the medial end of the muscle, which obliterates the superoposterior part of the cavity (arrows). The canal skin flaps are replaced

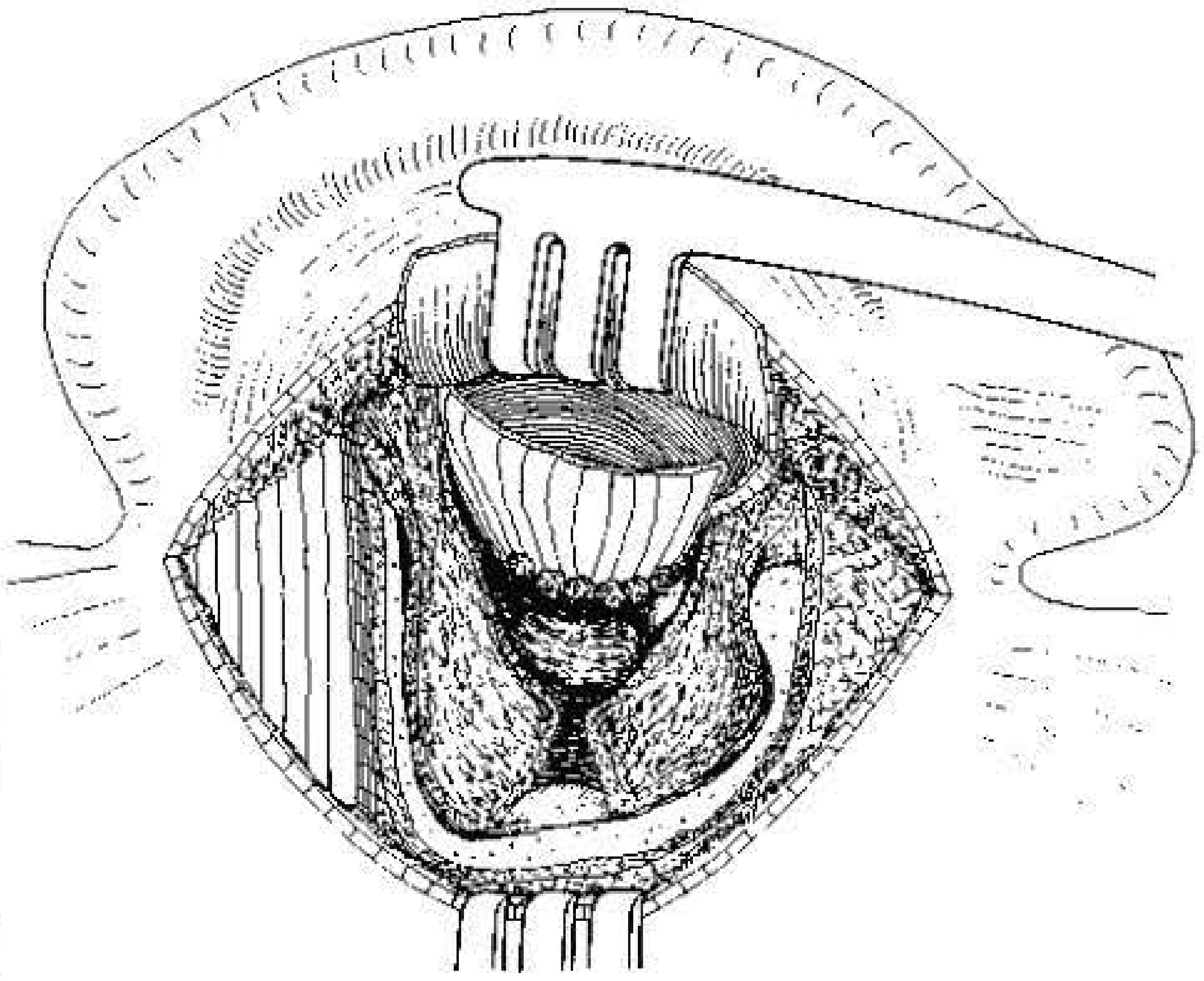


Fig. **792** The modified Palva flap is divided in two flaps, one based superoanteriorly and the other inferoanteriorly. They cover the superior and inferior parts of the cavity. Medially, the fascia has already been placed under the drum remnant and canal skin flaps, as well as onto the medial attic wall. It will be extended over the medial parts at the subcutis–muscle grafts

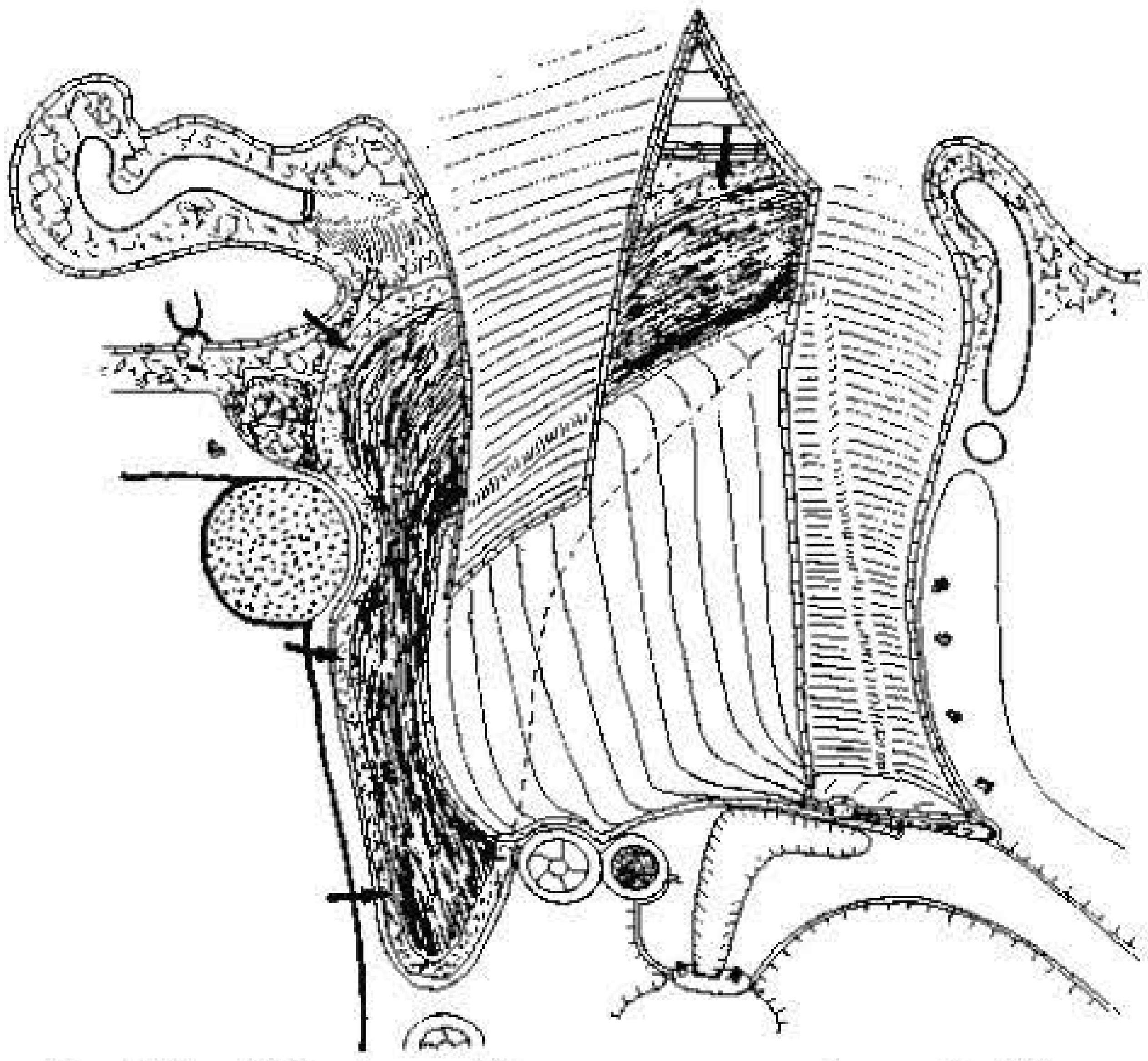


Fig. **791** Side view, with some perspective, of obliteration with a modified Palva flap and meatoplasty with resection of the conchal cartilage. The Palva flap covers the superior part of the cavity (arrows). The medial part is covered with a piece of fascia, extending over the medial part of the flap. Laterally, a Körner flap covers the subcutis–muscle flap, and posteriorly, some Gelfoam balls are placed in the cavity. The ear canal is wide

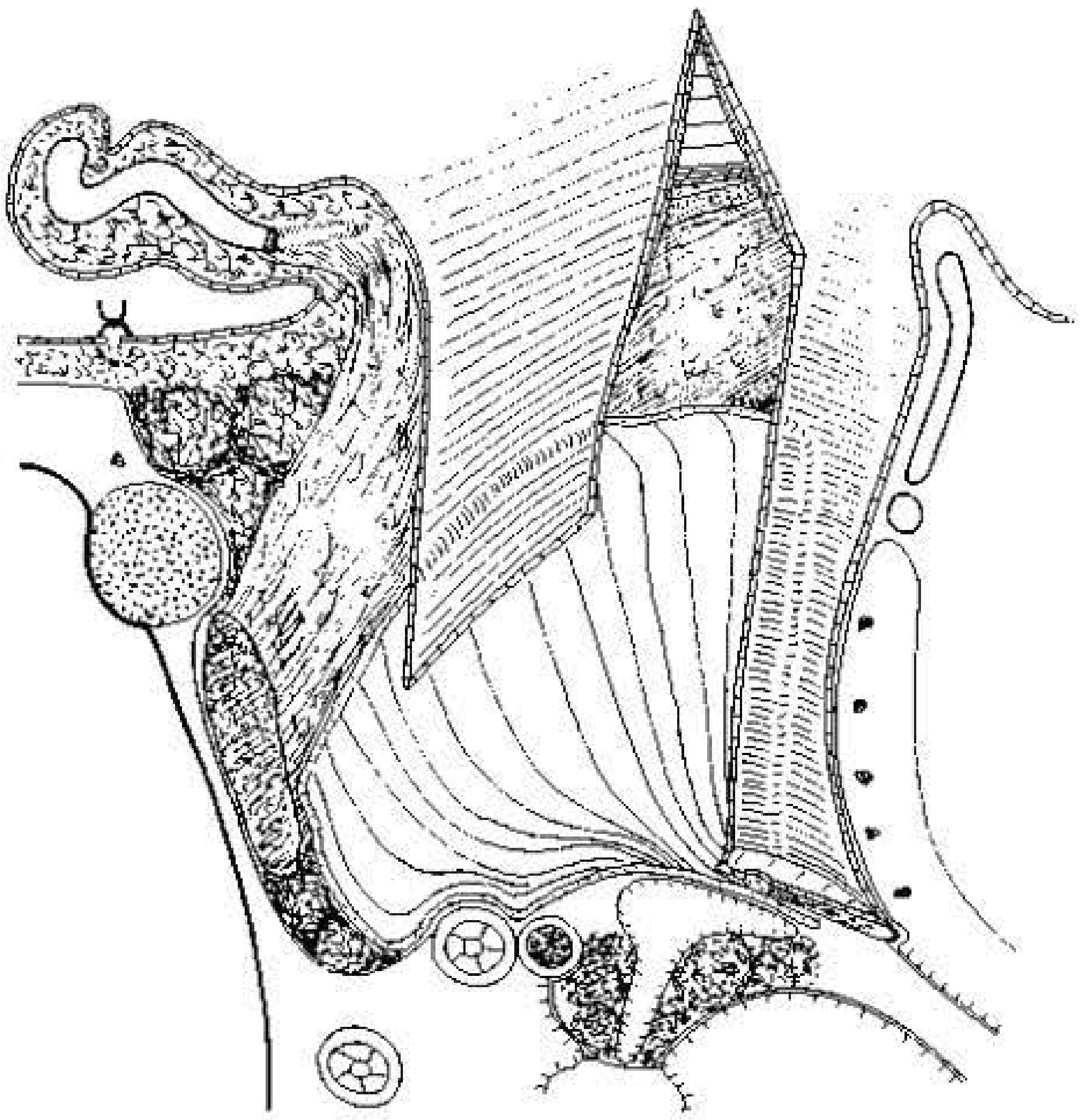


Fig. **793** Side view, with some perspective, of a meatoplasty and obliteration with a modified Palva flap. The subcutis–muscle flap covers the posterior and superior walls of the cavity. The medial cavity wall is covered with fascia, as is a part of the muscle. Laterally, the Körner flap covers the subcutis–muscle flap

16 Mastoid Tip Removal

Ablation of the mastoid tip is currently performed as a part of the reconstruction of the middle ear in cases with extensive pneumatization resulting in a huge cavity that cannot be sufficiently reduced using obliteration techniques. In the present author's opinion, today's ear surgeons do not pay enough attention to the procedures of mastoid tip removal, which can solve many problems relating to the inferior part of the cavity. With some exceptions, the surgical techniques of mastoid tip removal and the final outcome of these procedures are not described in textbooks of ear surgery. Indeed, lowering of the facial ridge down to the level of the facial nerve, along with maximum widening of the ear canal in order to survey the inferior part of the cavity, is often recommended and described (Zöllner 1959, Saunders and Paparella 1971, Paulsen 1974, Theissing and Theissing 1975, Portmann 1979, Fisch 1980, Kley 1982, Goycoolea et al. 1989, Plester et al. 1989, Charachon 1990, Glasscock and Shambaugh 1990, Sheehy 1990, Zini et al. 1993).

Ablation of the mastoid tip as a curative procedure is not a new idea, and was frequently used in the treatment of Bezold's abscess and mastoiditis, with perforation through the medial lamina of the mastoid tip.

In the 1930s, the method was mentioned as part of a cavity reconstruction after canal wall–down mastoidectomy in ears with massive pneumatization or extensive pathology in the mastoid tip. Guilford was the first to include mastoid tip ablation in modern middle ear surgery (Guilford et al. 1958). Fisch (1980, 1994) and Sheehy (1988) recommended removal of the mastoid tip in most cases of problematic, chronically discharging, previous radical cavities.

Guilford's Method

Worldwide use of the endaural approach with the Heermann, Lempert, Shambaugh, Farrior or Fleury incisions (Vol. 1, Chapter 4) and the dominant position of this approach in mastoid surgery, as opposed to the retroauricular approach that dominated prior to the popularization of the intact canal wall–up mastoidectomy technique by Jansen (1958, 1962, 1972), is one of the reasons why mastoid tip removal has not been applied. In the endaural approach, mastoid tip removal is practically impossible to perform, even with maximum extension of the incision around the auricle, for example in the Heermann C incision (Vol. 1, Figs. **48**, **49**).

In addition to the Shambaugh incision used routinely by Guilford (1960), a low retroauricular incision over the mastoid tip is employed if air cells are found extending into the mastoid tip area (Fig. **794**). The tip cells are gradually exenterated (Fig. **795**) down to the digastric crest, leaving only a thin cortex over the mastoid tip. Next, the periosteum and the muscle fibers attached to the mastoid tip are detached from the bone all the way around the mastoid tip (Fig. **796**) and the thin shell is gradually drilled away, starting at its posterior edge (Fig. **797**), and continuing around the mastoid tip as far as the level of the tympanomastoid suture

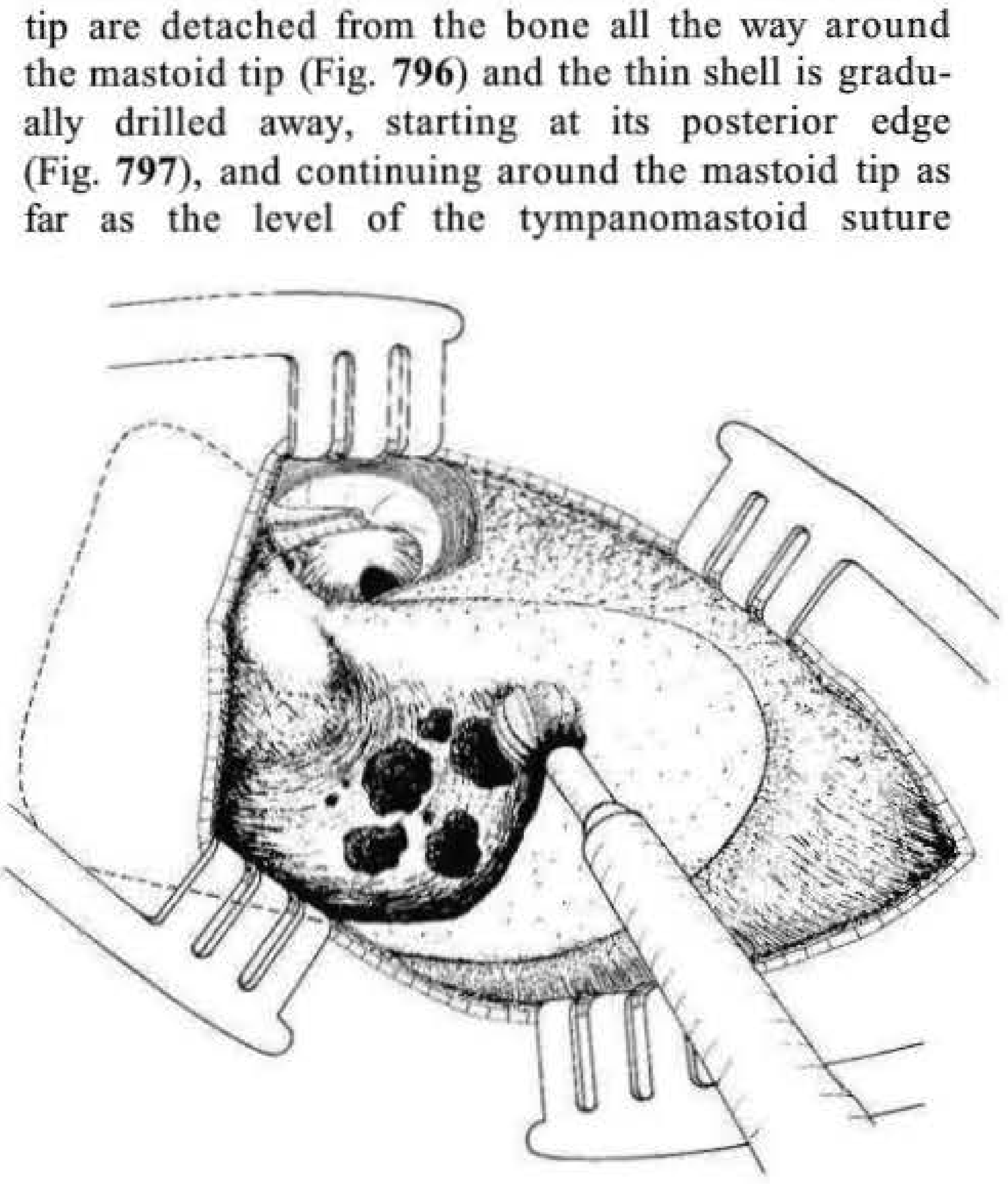


Fig. **794** **Guilford's mastoid tip removal.** After a canal wall–down mastoidectomy has been performed in an endaural approach and it has been recognized that the air cells and the pathology extend far down into the mastoid tip, a retroauricular incision over the mastoid tip is performed. The skin is elevated, and the mastoid tip is exposed by removal of the muscle fibers covering the mastoid tip. The air cells are exenterated using a large cutting burr. In the tympanic cavity, the incus is extruded, and the posterior part of the drum is elevated. The upper border of the endaural canal wall–down mastoidectomy cavity is indicated by a dashed line

(Fig. **798**). The mastoid portion of the facial nerve and the stylomastoid foramen lie medial to the tympanomastoid suture. The mastoid tip is eliminated as far as the level of the digastric crest (Fig. **799**). The facial ridge is maximally lowered, and the posterior part of the tympanic bone is drilled away (Fig. **800**).

Elevation of the periosteum and the muscle fibers from the mastoid tip are not absolutely necessary before drilling. Using a large diamond drill, the bone can be removed, leaving the periosteum and the muscle fibers attached.

The detached periosteum and the sternocleidomastoid muscle fibers are pressed onto the bone (Fig. **801**), covering the most distal part of the mastoid tip. The wound is closed, whilst overlying and surrounding fibrous tissue covers the inner table of the mastoid process. The outer dressing presses the auricle medially, securing the inferior part of the cavity and the mastoid tip area. Of course, a tympanoplasty and a meatoplasty have to be performed to manage the upper part of the cavity as an open cavity: alternatively, an obliteration using a superiorly-based temporalis muscle flap can be performed.

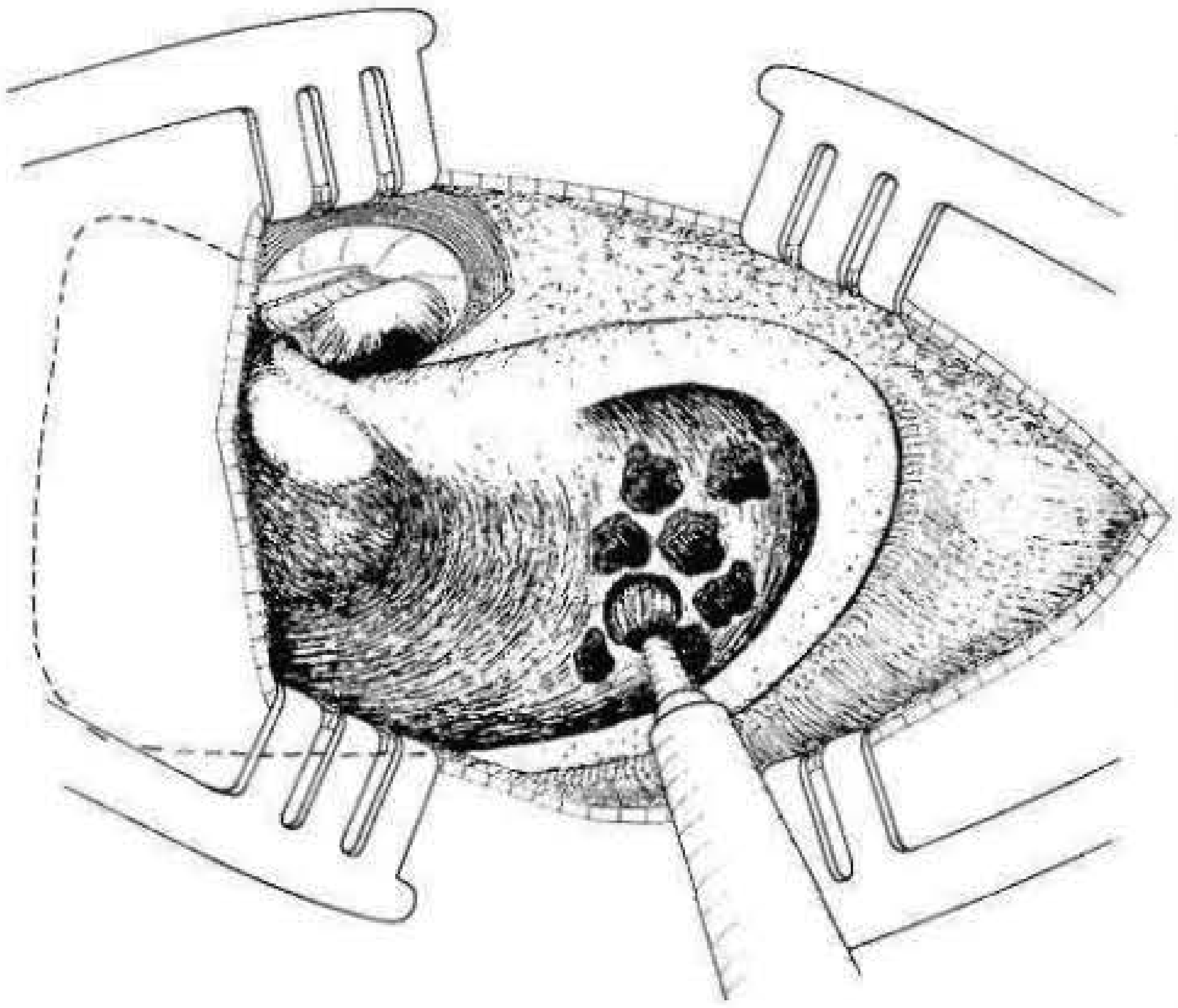


Fig. **795** The mastoid tip cells are further exenterated, and all the cortical bone of the mastoid tip is exposed

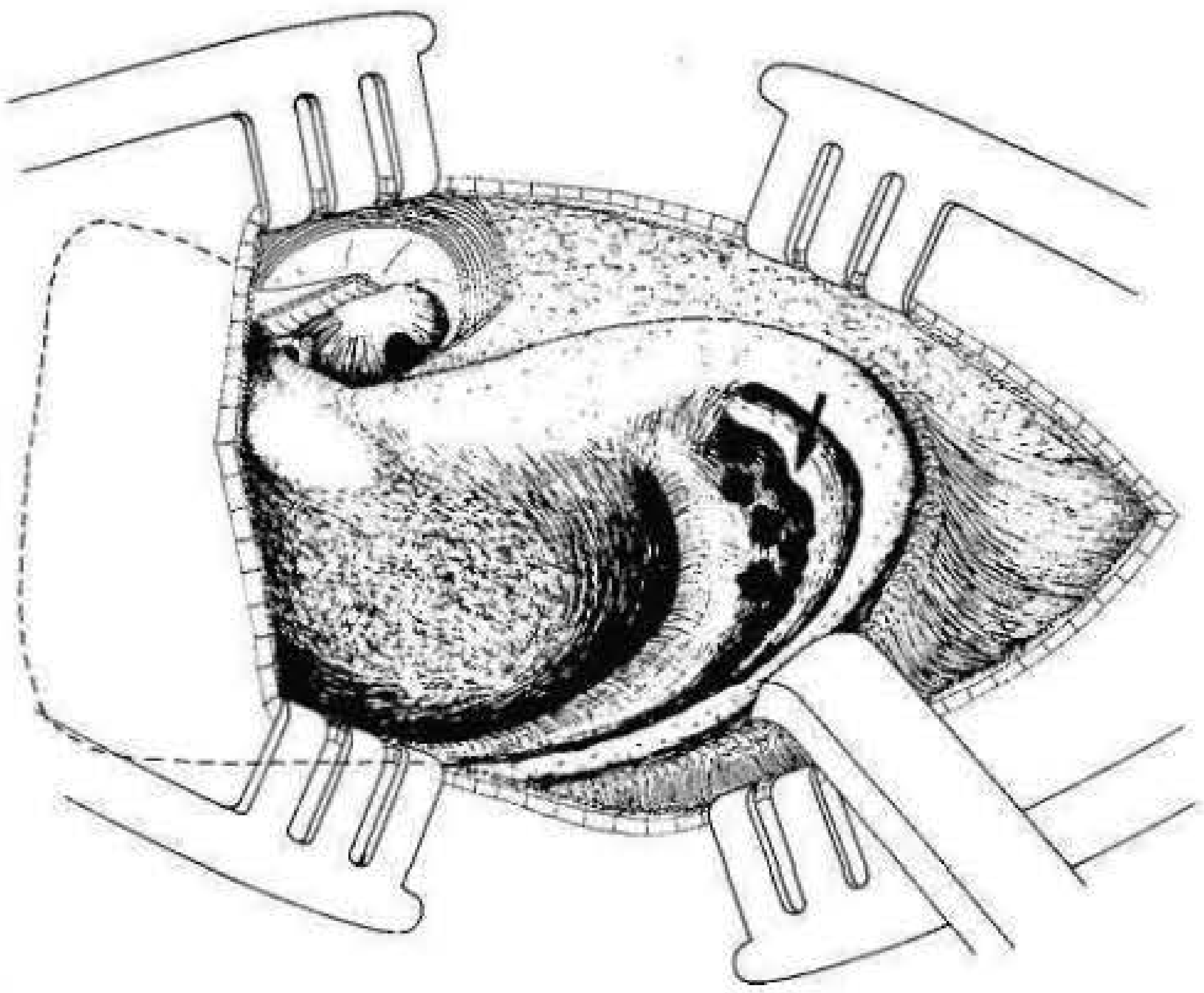


Fig. **796** The mastoid tip air cells are exenterated down to the digastric crest (arrow). There are still some deep cells between the sigmoid sinus and the digastric crest. Around the mastoid tip, the periosteum and muscle fibers are elevated with a periosteal elevator

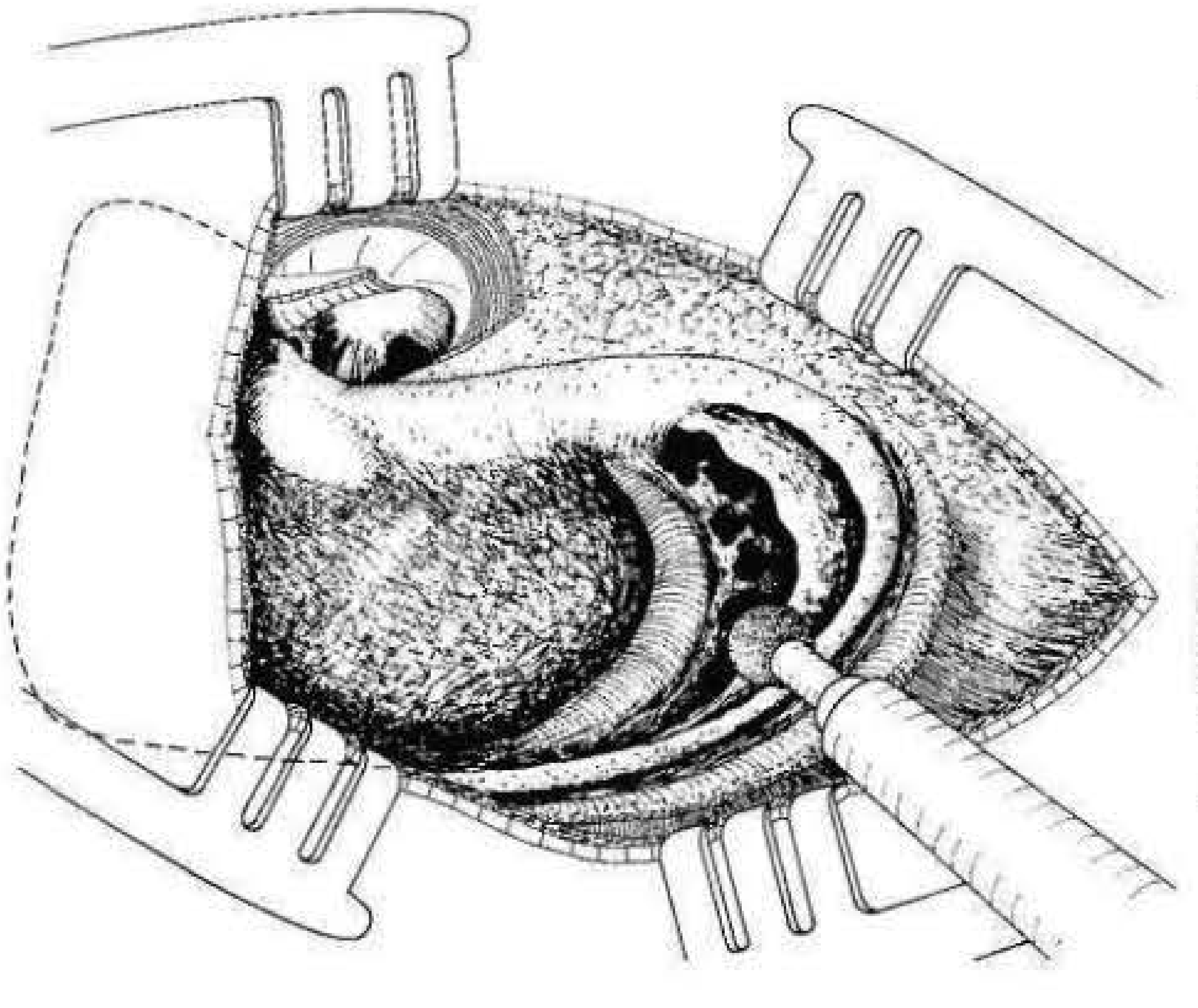


Fig. **797** The thin cortex of the mastoid tip is drilled away, starting with a large diamond burr at the posterior **edge, and continuing down the tip**

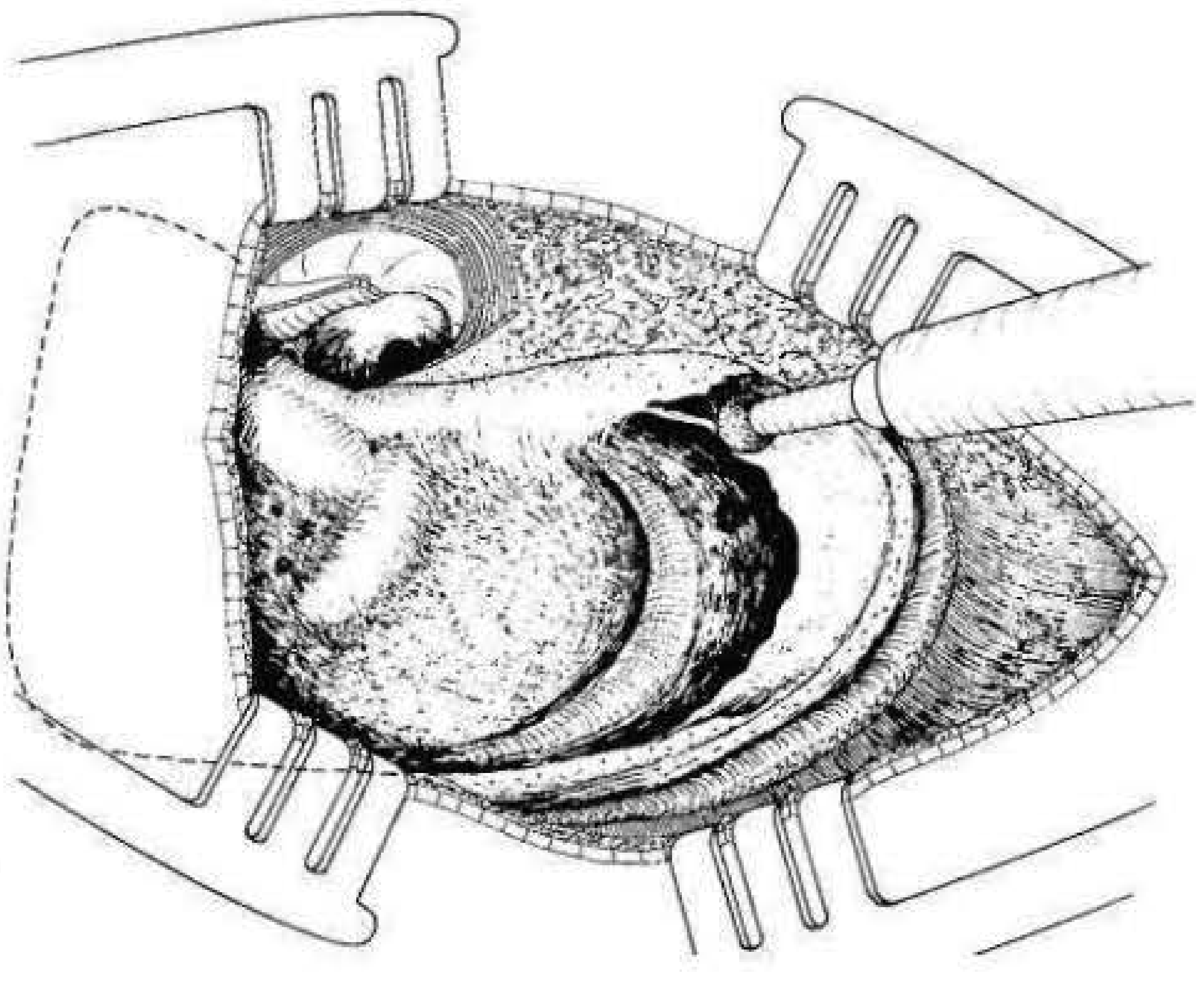


Fig. **798** The posterior and inferior cortex of the mastoid tip is removed. The drilling continues along the anterior border of the mastoid tip cortex

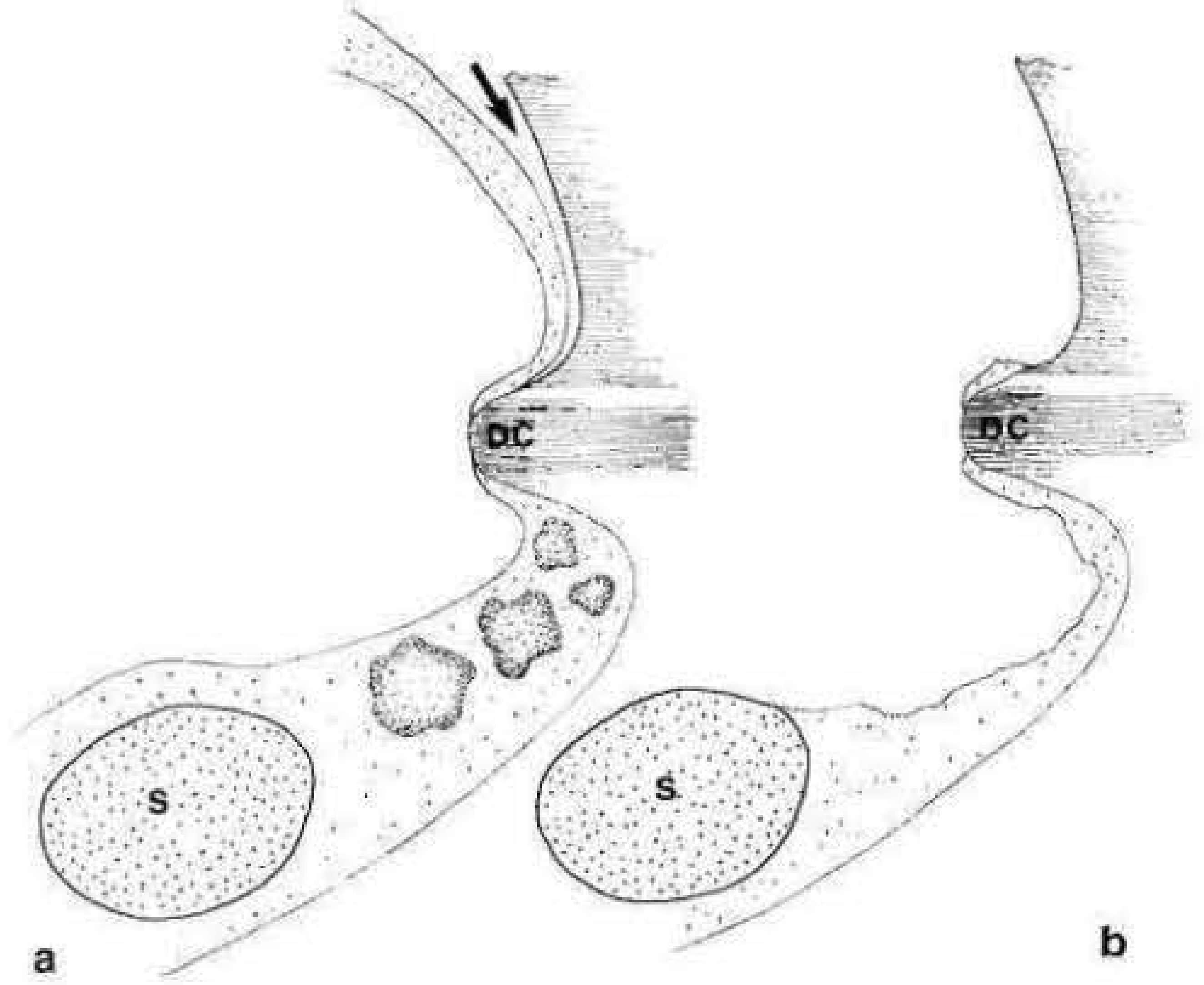


Fig. **799** Side view of the mastoid tip cortex. **a** After exenteration of the cells, the digastric crest (D) is exposed to a whitish area consisting of periosteum fibers. Laterally to it, the cortical bone of the tip is still in place, and the periosteum (arrow) is elevated from the cortical bone. Medial to the digastric crest, there are still some air cells between the digastric crest and the sigmoid sinus (S). **b** The cortical bone from the mastoid tip is removed up to the digastric crest, which is exposed. The cells located medially to the digastric crest and inferiorly to the sigmoid sinus are exenterated

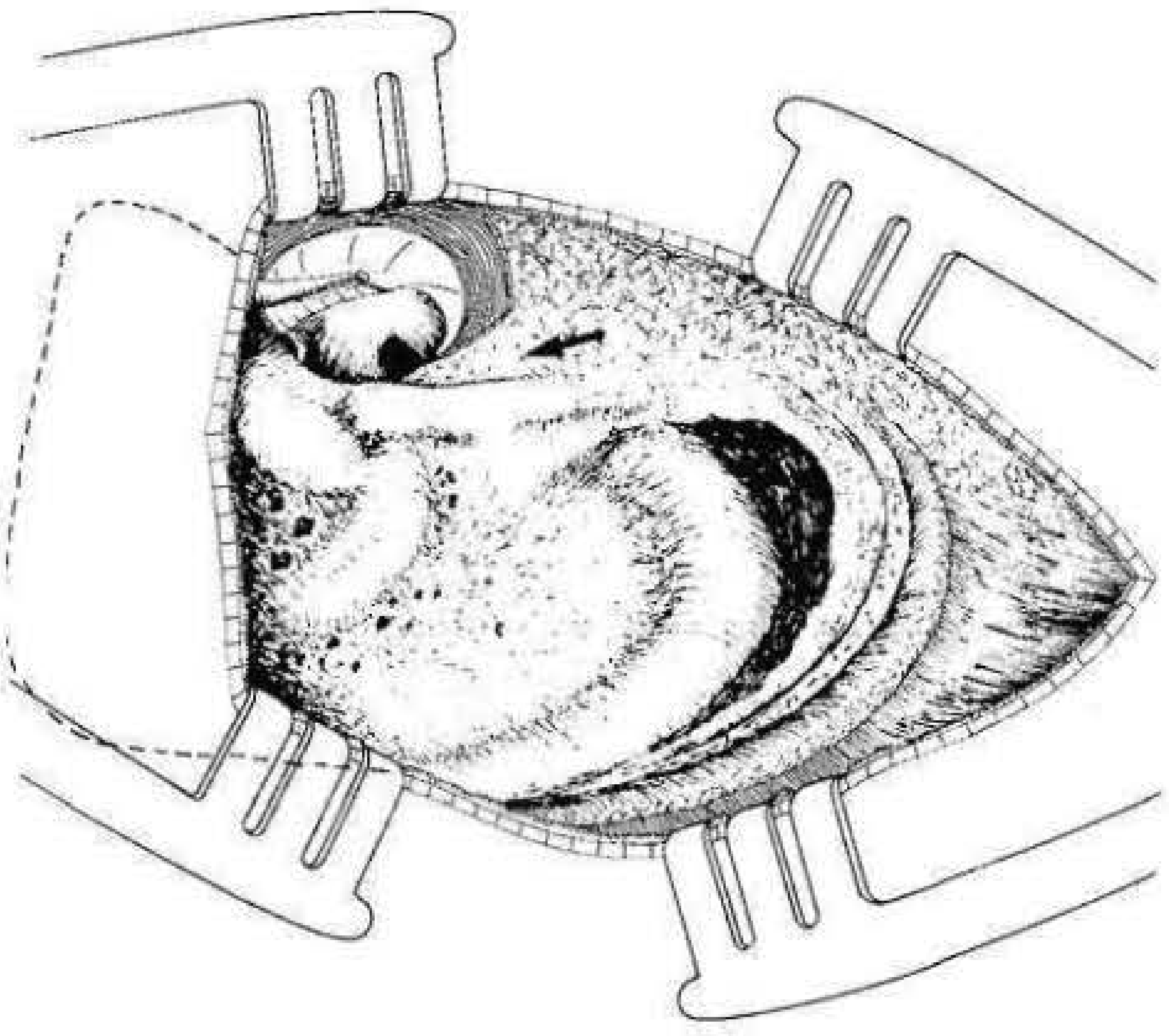


Fig. **800** All cortex from the mastoid tip is removed, and the facial ridge is maximally lowered and completely eliminated. The posterior part of the tympanic bone (arrow) is drilled away, making a gradual transition from the tympanic bone to the mastoid tip

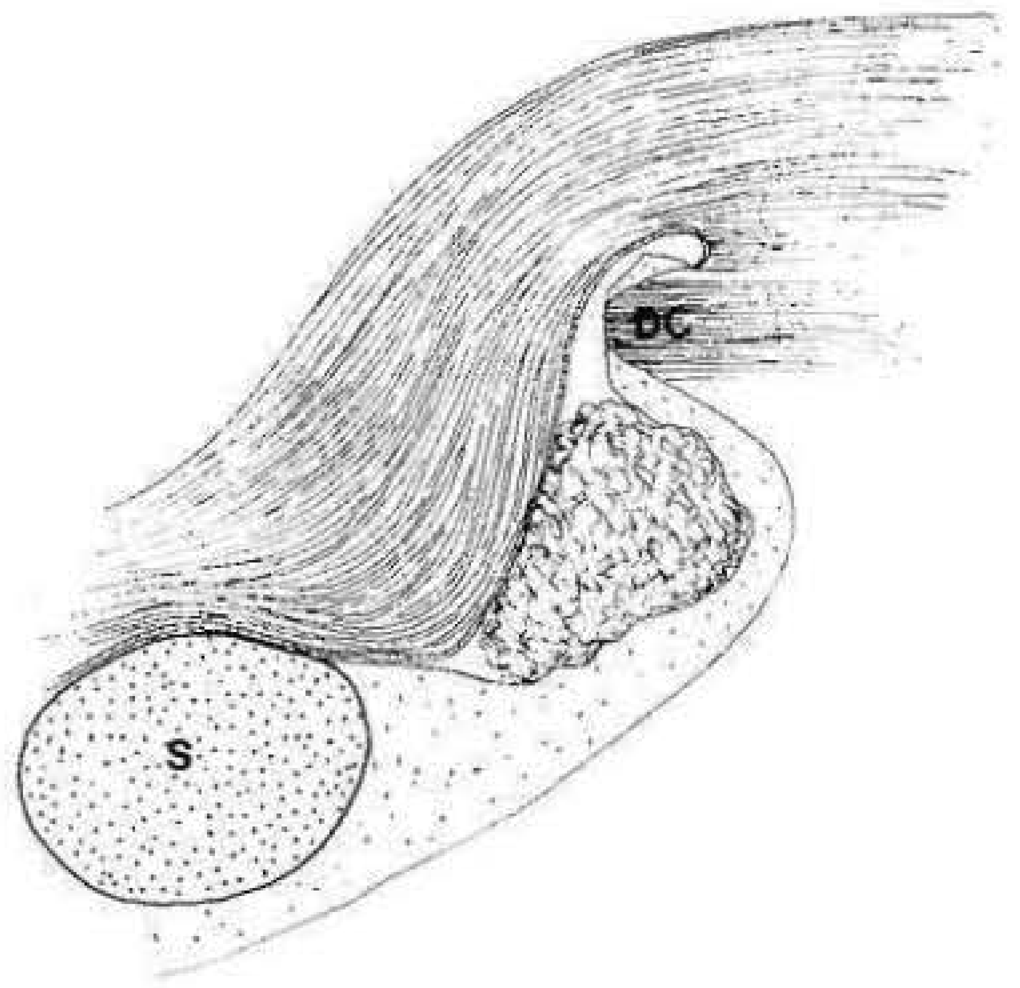


Fig. **801** The detached musculoperiosteal tissue from the mastoid tip covers the digastric crest and the most inferior part of the mastoid tip area. A Gelfoam ball (or a free muscle graft) is placed in the deepest part of the cavity, between the digastric creast and the sigmoid sinus. S: sigmoid sinus; DC: digastric crest

Obliteration of the Mastoid Tip Area

If the mastoid tip area is deep, with exenterated air cells extending between the digastric crest and the sigmoid sinus, the cavity can be obliterated. The obliteration involves the entire inferior half of the mastoid cavity. Guilford (1960) used two flaps. The first flap is cut from the posterior region of the mastoid process, and is inferoposteriorly based (Fig. **802**). Its superior part consists of fibrous tissue and periosteum. Its inferior part consists of splenius capitis muscle and transversus nuchae muscle fibers. In order to harvest the flap posteriorly, the skin has to be elevated extensively. The flap is placed in the posterior part of the cavity (Fig. **802**).

In order to obliterate the anterior part of the mastoid tip, a piece of sternocleidomastoid muscle can be dissected as an inferiorly-based flap, and turned into the mastoid tip area (Fig. **803**). Guilford placed a guide suture in the upper end of the flap to pull it through the cavity and the external auditory canal, in order to hold the flap in place while the retroauricular incision is closed with sutures.

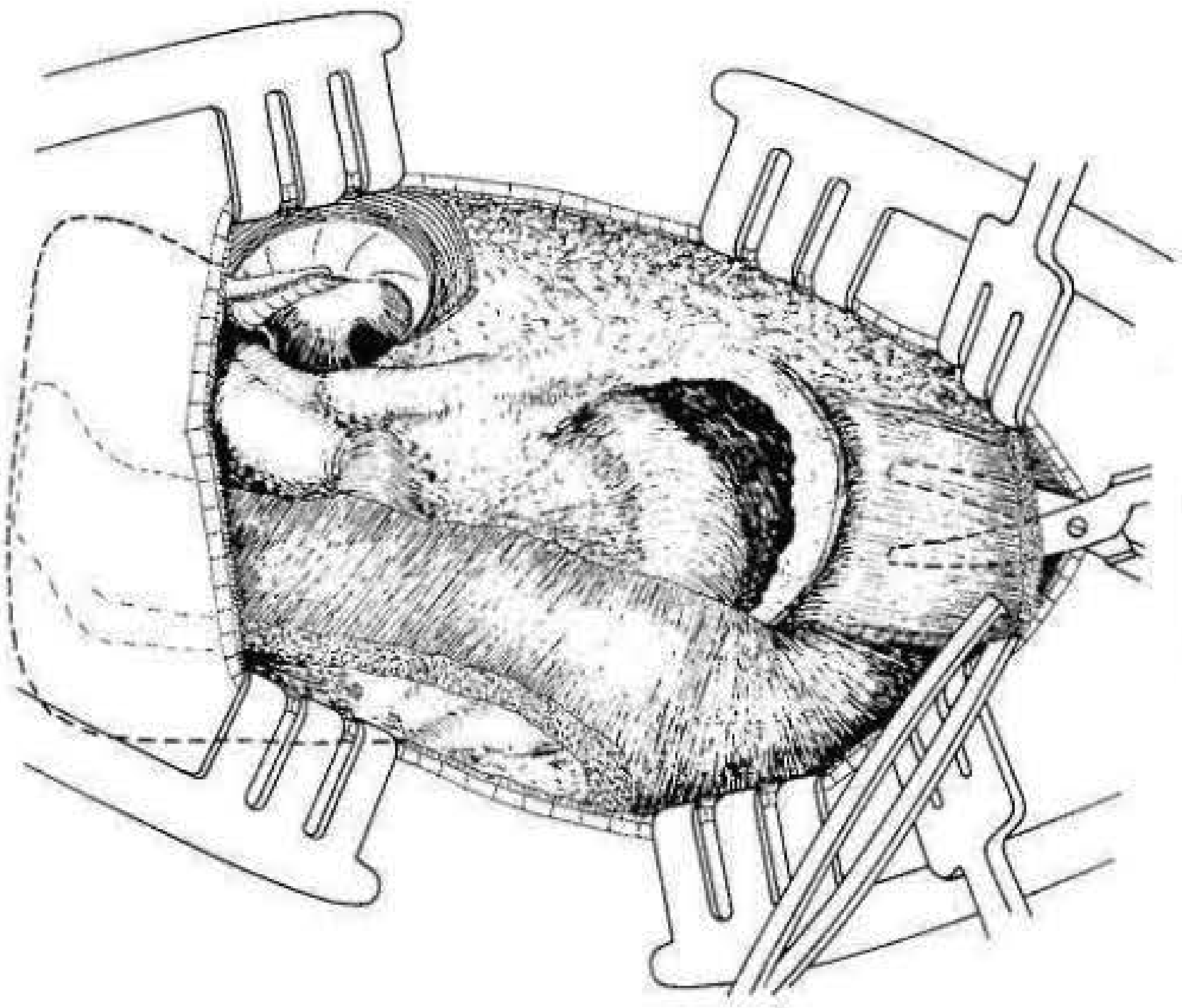


Fig. **802** **Guilford's obliteration of the mastoid tip area.** An inferiorly-based flap, consisting of muscle fibers and fibrous tissue harvested from the region behind the cavity, is placed in the posterior part of the cavity. The flap is based inferoposteriorly. The present author covers the anterior part of the mastoid tip area with a small muscle flap, elaborated from the sternocleidomastoid muscle

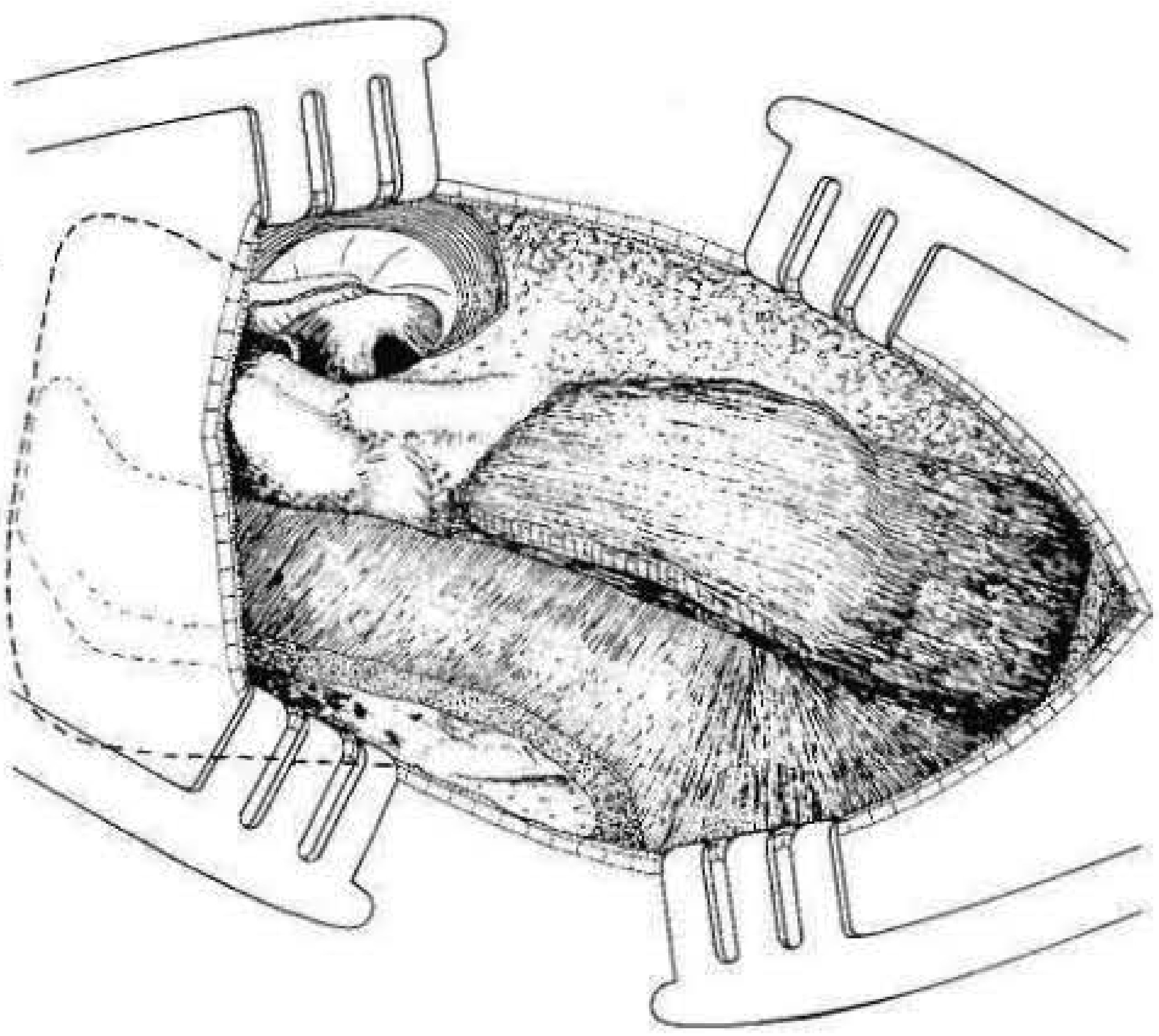


Fig. **803** The small muscle flap covers the exposed mastoid tip area anteriorly

Using the endaural approach, Guilford placed one ear canal skin flap along the facial ridge and another over the roof of the cavity. The lower extremity of the cavity is now at the level of the floor of the external auditory canal. The upper part of the cavity can be obliterated with a superiorly-based temporalis muscle flap, placed in the sinodural angle region. After meatoplasty with maximal dilation of the external meatus, the ear canal is packed, and a moderately tight mastoid dressing is applied over the previously sutured retroauricular incision in order to maintain the pressure over the tip area.

Retroauricular Approach

The retroauricular approach is the approach of choice in cases with extensive pneumatization in which removal of the mastoid tip is indicated. This procedure is seldom performed, because a canal wall–up mastoidectomy is usually used in cases with extensive pneumatization. However, if the intact canal wall procedure fails, mastoid tip removal is indicated to diminish the size of the cavity. The present author employs a method of mastoid tip removal which is used to expose the sigmoid sinus in translabyrinthine surgery for acoustic neuromas.

When performing canal wall–down mastoidectomy in cases with extensive pneumatization posterior and inferior to the sigmoid sinus (Fig. **804**), the author starts by skeletonizing the sigmoid sinus, exenterating all perisinusal cells, and lowering, so that the transition from the occipital region to the sigmoid sinus is smooth without any edges (Fig. **805**). Exenteration of the air cells proceeds toward the mastoid tip, and at the same time the posterior wall of the mastoid tip is drilled away to the level of the inferior part of the sigmoid sinus (Fig. **805**). The drilling continues, skeletonizing the inferior part of the sigmoid sinus and the digastric crest, and exenterating the deep apical cells lying between the digastric crest and the sigmoid sinus (Fig. **806**). Removal of the bony cortex of the mastoid tip is continued anteriorly, and care is taken by using a diamond drill at the level of the digastric crest (Fig. **807**). With further drilling along the course of the facial nerve, the facial ridge is lowered as far as the tympanomastoid suture. The lowered tympanic bone provides a smooth transition from the facial ridge to the inferior part of the ear canal (Fig. **808**). The mastoid tip is smoothed completely, leaving no overhangs or sharp edges, and resulting in a smooth transition from the occipital region to

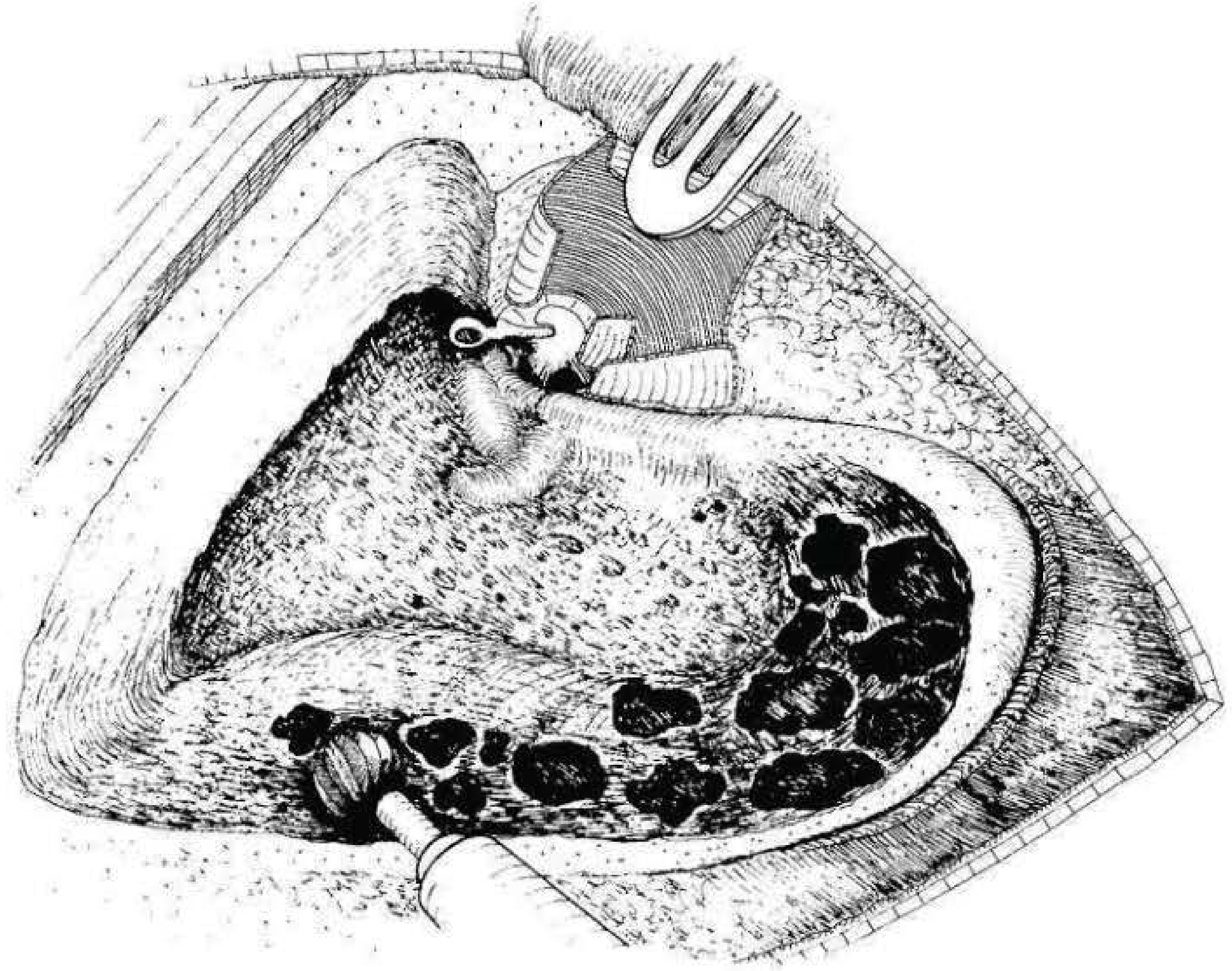


Fig. **804** **Mastoid tip removal in a retroauricular approach.** After a large retroauricular skin incision and elevation of the subcutis–periosteal tissue, a large Palva flap is elaborated and a canal wall–down mastoidectomy, with removal of the bridge, extrusion of the incus, and exenteration of all cells from the posterior part of the cavity, is performed. Behind the sigmoid sinus, large air cells, continuing down into the mastoid tip, are exenterated using a cutting burr

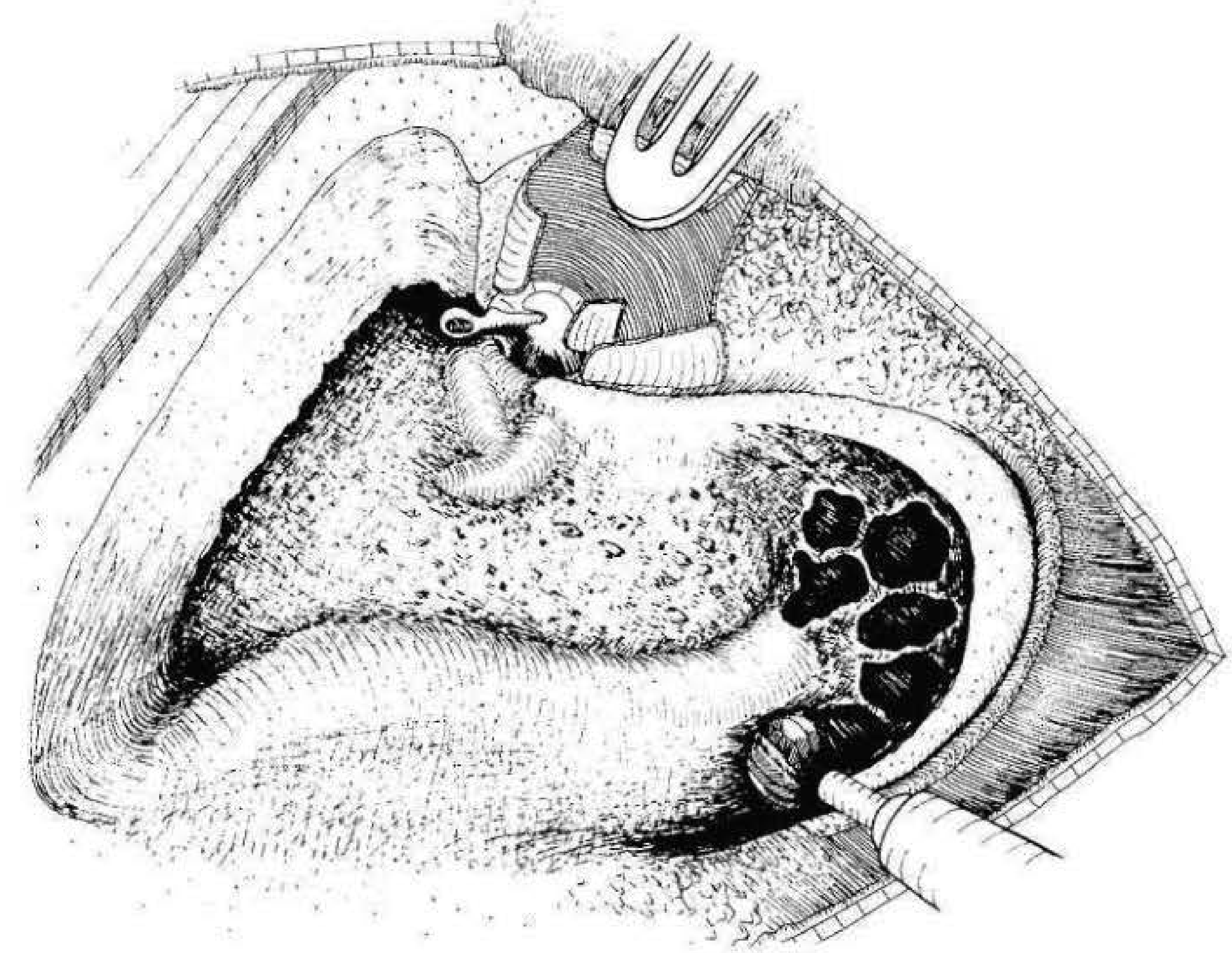


Fig. **805** The perisinusal air cells are removed. The sigmoid sinus is skeletonized and the cortical bone behind the sinus is polished, making the transition from the surface of the cortex to the posterior part of the mastoid cavity smooth. Simultaneously with the exenteration of the mastoid tip cells, the cortical bone lying posterior to the mastoid tip is drilled away

the sigmoid sinus and posterior fossa dural plate region.

The mastoid tip area and the inferior part of the cavity can be obliterated with inferiorly or posteriorly based muscle flaps.

Kahramanyol (1992) published promising results using a canal wall–down procedure, saucerization of all bony buttresses, and removal of the mastoid tip and of all diseased tissues before covering the mastoid cavity with an inferiorly based subcutis–periosteum flap and creation of a large meatoconchoplasty.

In a retroauricular approach with extensive elevation of the skin and subcutaneous tissue, includ-

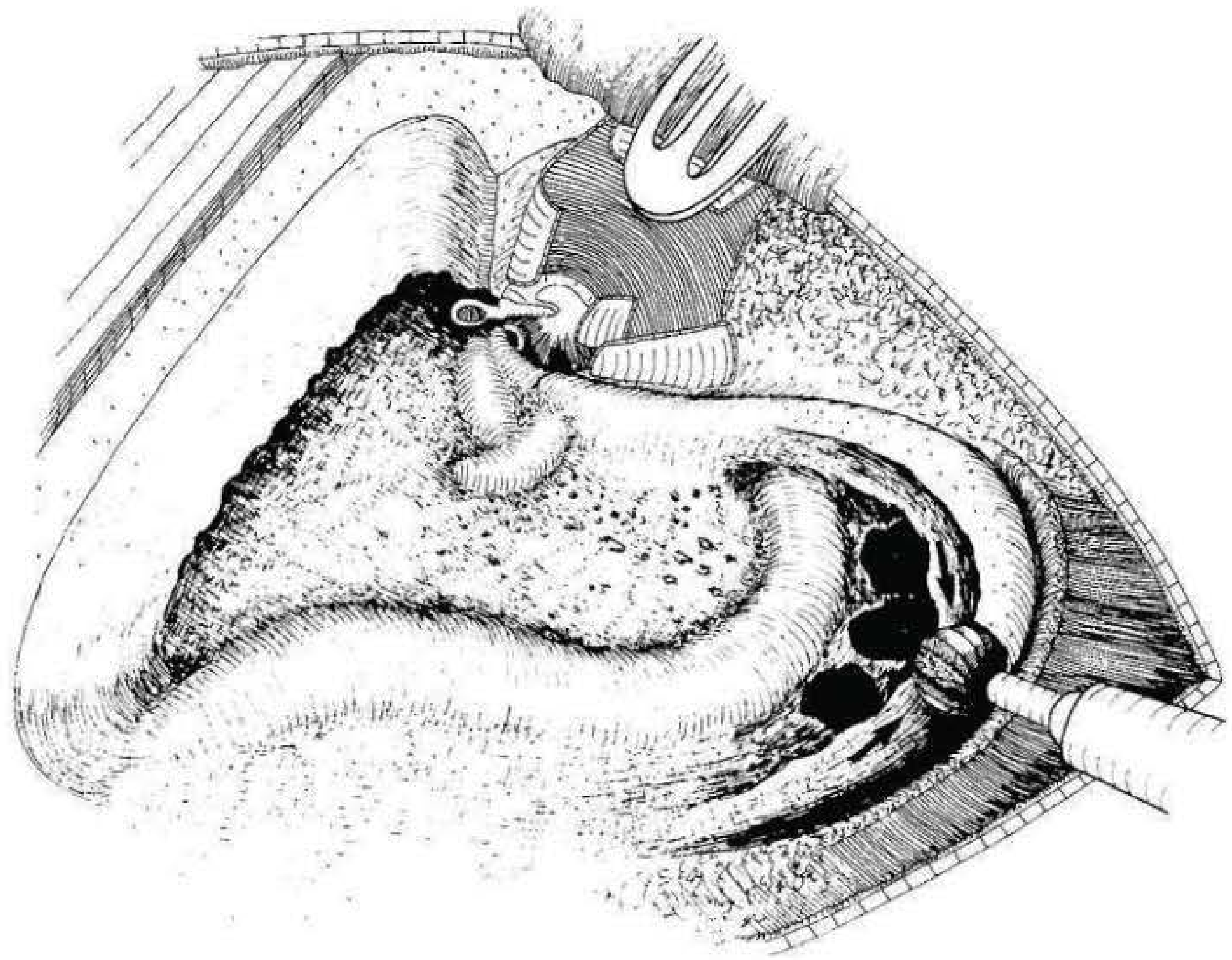


Fig. **806** The mastoid tip cortex and all the cells are drilled down to the level of the digastric crest (arrows) and to the level of the skeletonized sigmoid sinus

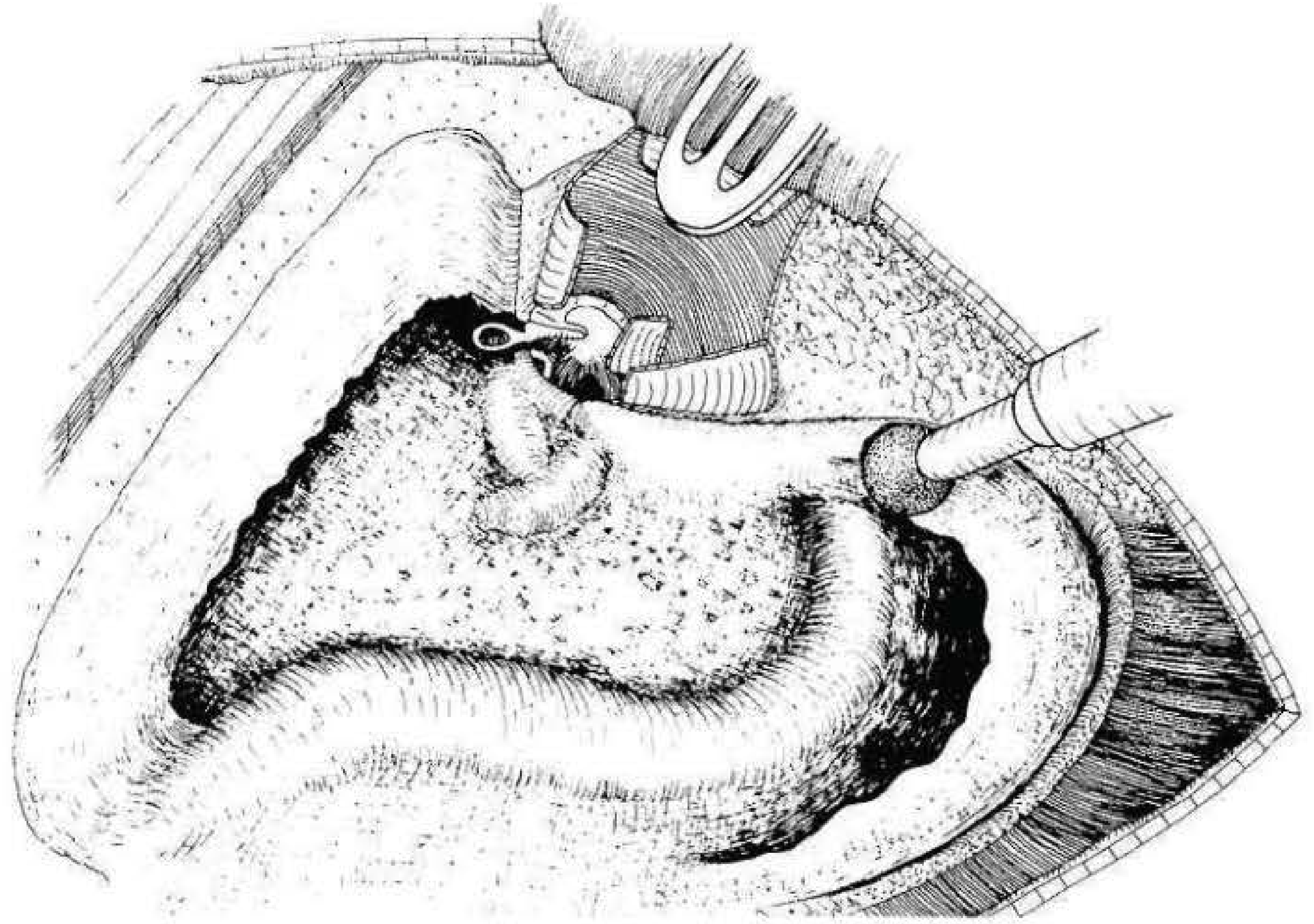


Fig. **807** The cells between the digastric crest and the **sigmoid** sinus are removed, the cortical bone of the mastoid tip is removed up to the digastric crest, **and** drilling continues toward the anterior part of the mastoid tip

ing the postauricular muscle, the periosteal flap is harvested using a superior incision along the inferior border of the temporalis muscle (Fig. **809**). The anterior incision goes around the meatus to the mastoid tip, and the posterior incision runs as far posteriorly as possible. The periosteum is carefully elevated inferiorly. exposing the mastoid tip (Fig. **810**). After canal wall–down mastoidectomy with mastoid tip removal, the denuded bone of the cavity is then covered by this subcutis–periosteal flap (Fig. **811**), and the ear canal is widened with a meatoplasty.

The philosophy behind this technique, which is not an obliteration method, is to facilitate new bone formation through the periosteal flap, and Kahramanyol has shown that such cavities become smaller over time.

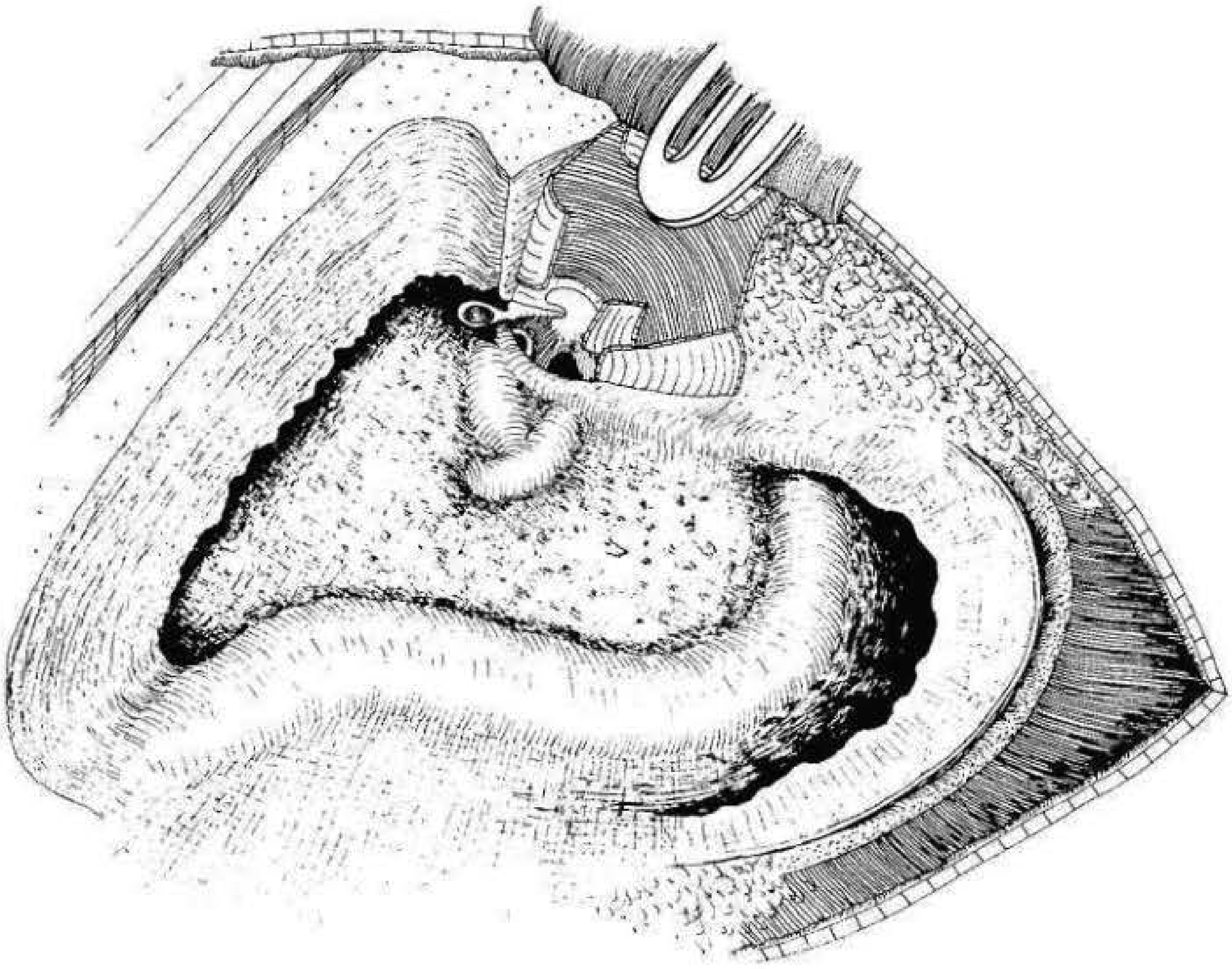


Fig. **808** The facial ridge and the tympanic bone are maximally lowered, allowing a smooth transition to the cortical bone and the digastric crest. All the mastoid tip is removed, and the walls are smoothed

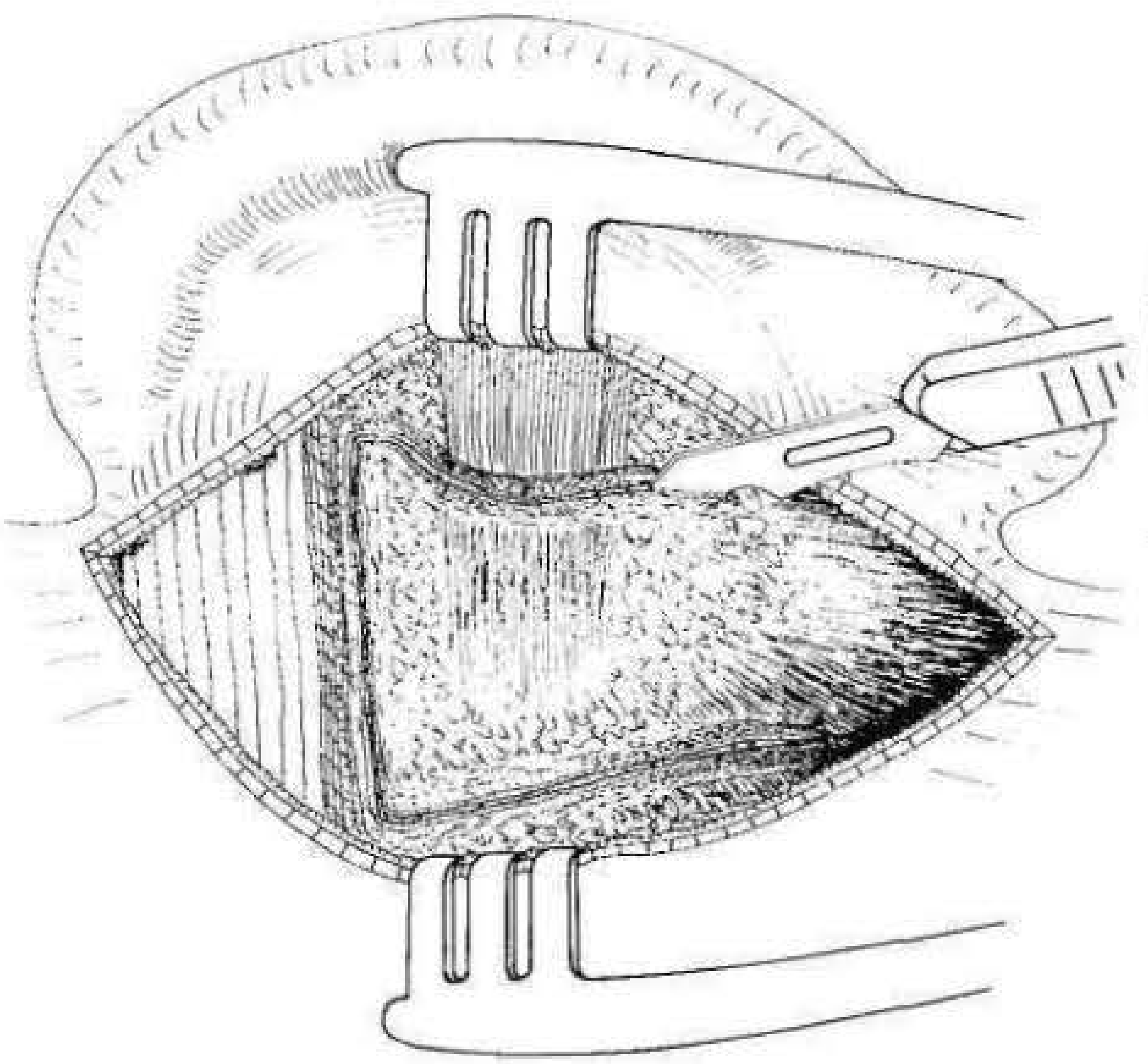


Fig. **809** Covering the removed mastoid tip wall and the cavity walls with a subcutaneous–periosteal flap (Kahramanyol 1992). After the retroauricular approach, a horizontal incision along the inferior border of the temporalis muscle, an anterior vertical incision along the ear canal, and a posterior incision far posteriorly are performed, elaborating a subcutaneous–periosteal flap

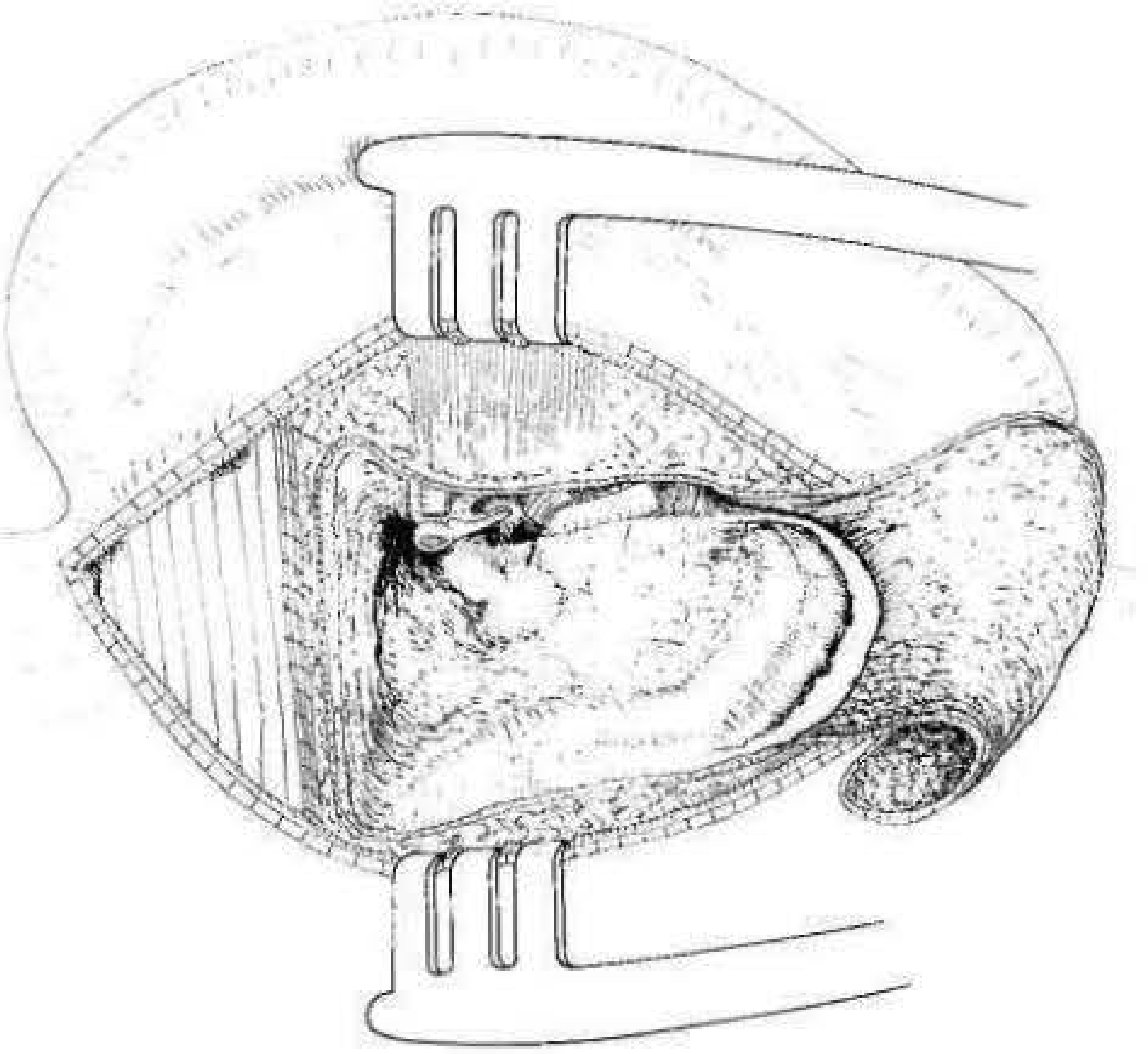


Fig. **810** The flap is elevated, a large cavity is created, and all the walls of the mastoid tip are removed

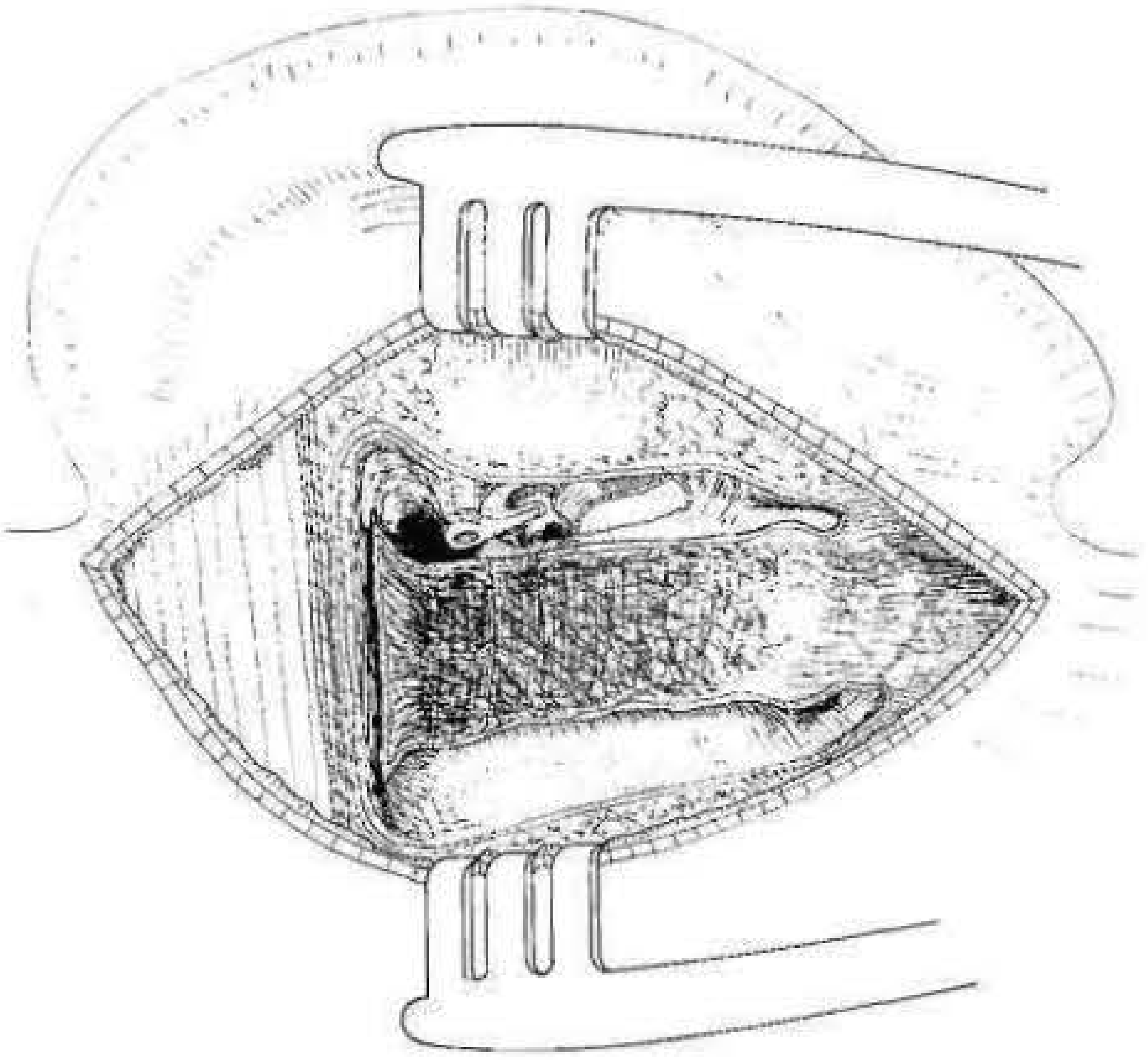


Fig. **811** The cavity walls and the mastoid tip area are covered with the subcutaneous–periosteal flap. The periosteum lies on the bone, promoting new bone formation

Reducing the Upper Part of the Cavity

In large cavities, besides an extensive meatoplasty, removal of the mastoid tip, extreme lowering of the facial ridge, and lowering of the retrosigmoid cortical bone (Fig. **807**), the cortical bone lateral to the sinodural angle and middle fossa dural plate has to be removed as well. Bone removal continues anteriorly as far as the zygomatic root (Fig. **812**). Starting with a large cutting burr laterally in the sinodural angle, the cortical bone is drilled away along the cavity edge, about 5–8 mm superior to the temporal line. Bone removal at the upper edge of the cavity and the temporal squama may extend as far as the internal bony plate and the dura.

After meatoplasty using an open cavity technique, or after obliteration when employing a closed cavity technique, the position of the auricle will depend on the cavity shape (Fig. **813**a) and whether the sharp edges are deeper (Fig. **813**b). In deep cavities with sharp, high edges, the auricle is usually pressed into the cavity during the meatoplasty, often resulting in deformity of the auricle. In cases with low edges, the auricle will fall naturally into the cavity.

Polishing the edges of the cavity is also very important in obliteration techniques, allowing far better placement of the muscle flaps.

Extensive removal of cortical bone when reducing the superior and posterior parts of the cavity as well as the mastoid tip, is the best source for the harvesting of the bone paté, particularly when drilling well away from the cholesteatoma.

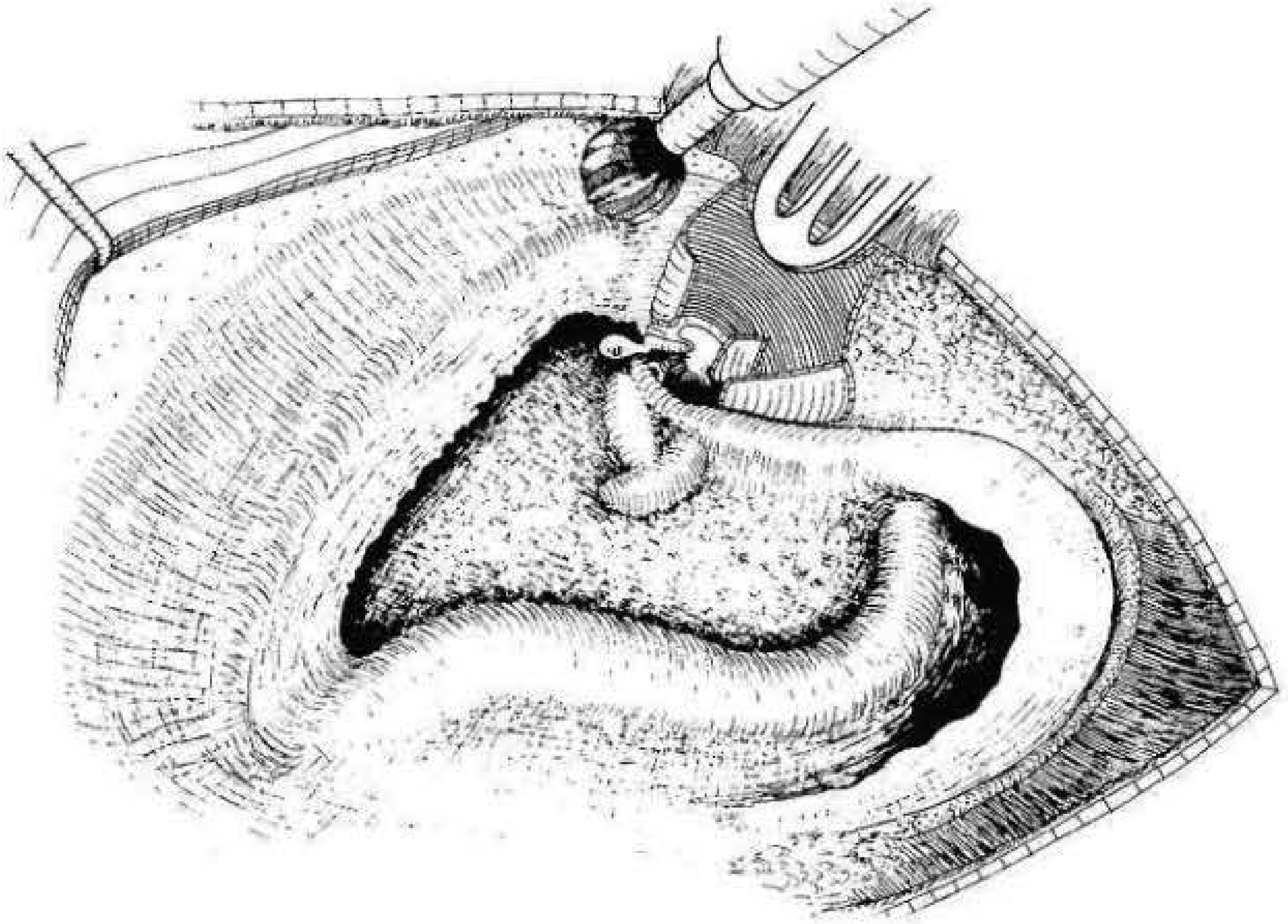


Fig. **812** **Removal of bone from the upper edge of the cavity.** In a situation with a large cavity, the upper edge and the cortical bone of the temporalis squama are removed for about 5–8 mm superiorly. The removal starts laterally in the sinodural angle, and continues anteriorly up to the zygomatic root. The entrance to the cavity will be smoothed and the cavity lowered

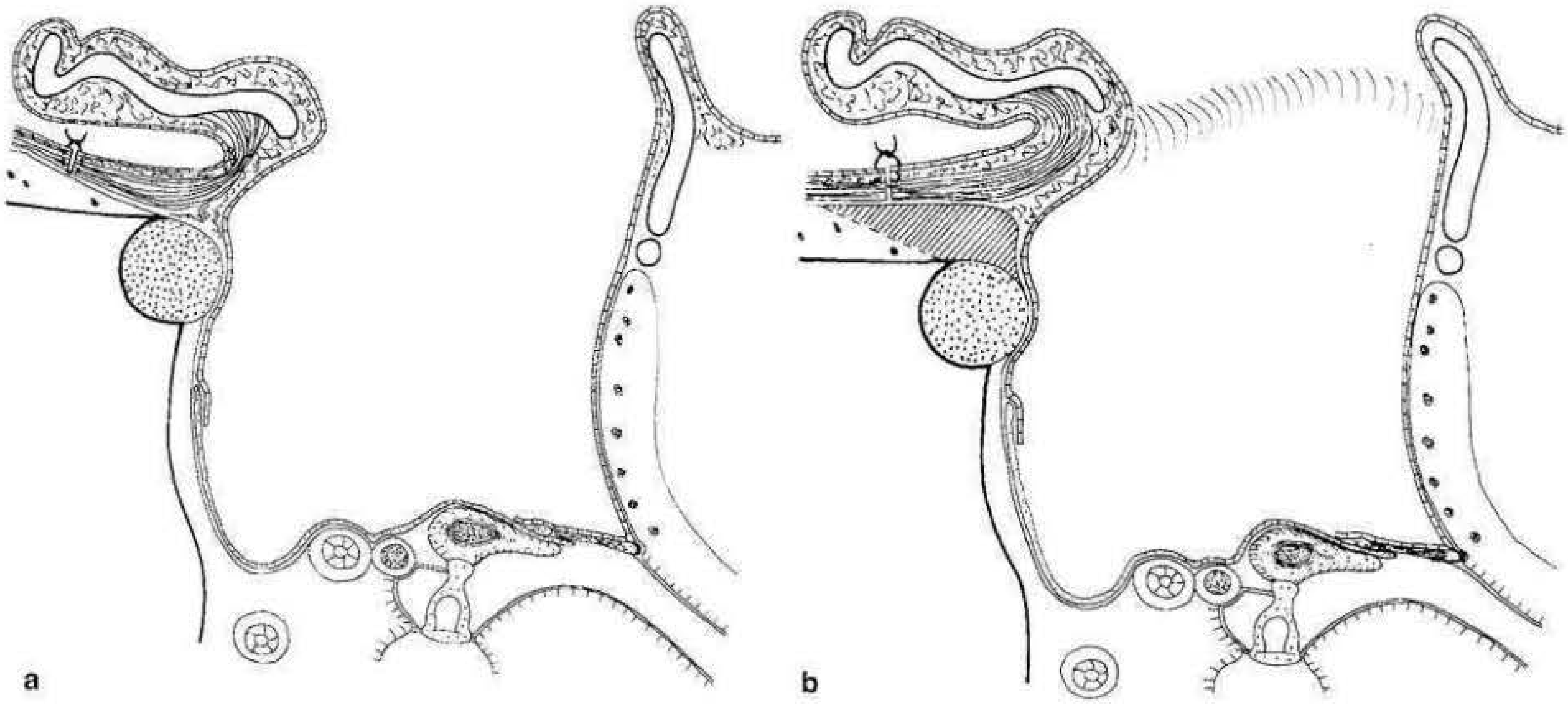


Fig. **813** Side view of the open cavity, **a** with a lowered posterior wall, allowing a lower position of the auricle and a smaller cavity. **b** The bone behind the sigmoid sinus is not removed, the cavity is higher, and the auricle is more laterally positioned

17 Reconstruction of the Posterior Ear Canal Wall

Reconstruction of the ear canal wall is performed after canal wall–up or canal wall–down mastoidectomy.

In canal wall–up mastoidectomy, only part of the bony ear canal wall is missing, either because of spontaneous resorption, typically found in attic cholesteatoma, or after partial removal of the ear canal wall in order to eradicate the disease. Sometimes both of these possibilities are present at the same time. In such cases, partial reconstruction of the ear canal wall, also called scutumplasty, is performed, as described in Chapters 6 and 7.

After canal wall–down mastoidectomy, the entire posterior ear canal wall is missing, and it can be either totally or partially reconstructed (Table **12**). In *total reconstruction* of the ear canal wall, the mastoid cavity can be either ventilated or obliterated. Obliteration can be partial, e. g., the mastoid tip alone, resulting in a cavity that is only partially ventilated.

In *partial reconstruction* of the ear canal wall after canal wall–down mastoidectomy, the bridge is usually reconstructed in order to achieve a high tympanic cavity, and in some cases also to ventilate the attic. In cases with a preserved bony bridge, the lateral attic wall is reconstructed using a piece of cartilage or bone to secure ventilation of the attic, and this form of reconstruction of the attic is also used in cases with an absent bridge.

Total Reconstruction with Ventilation of the Cavity

Reconstruction of the ear canal wall with ventilation of the mastoid cavity can be a dubious procedure, especially if ventilation of the cavity is insufficient at any stage following surgery. In such situations, the ear canal wall, which has been reconstructed using soft tissue, may retract and adhere to the cavity walls, resulting in an “open” cavity, which is a reasonable outcome. However, in cases where reconstruction of the ear canal wall has been performed using hard tissues, such as autogenous bone or hydroxyapatite, retraction pockets may similarly occur, located between the medial edge of the reconstructed ear canal wall and the drum, resulting in an unstable situation.

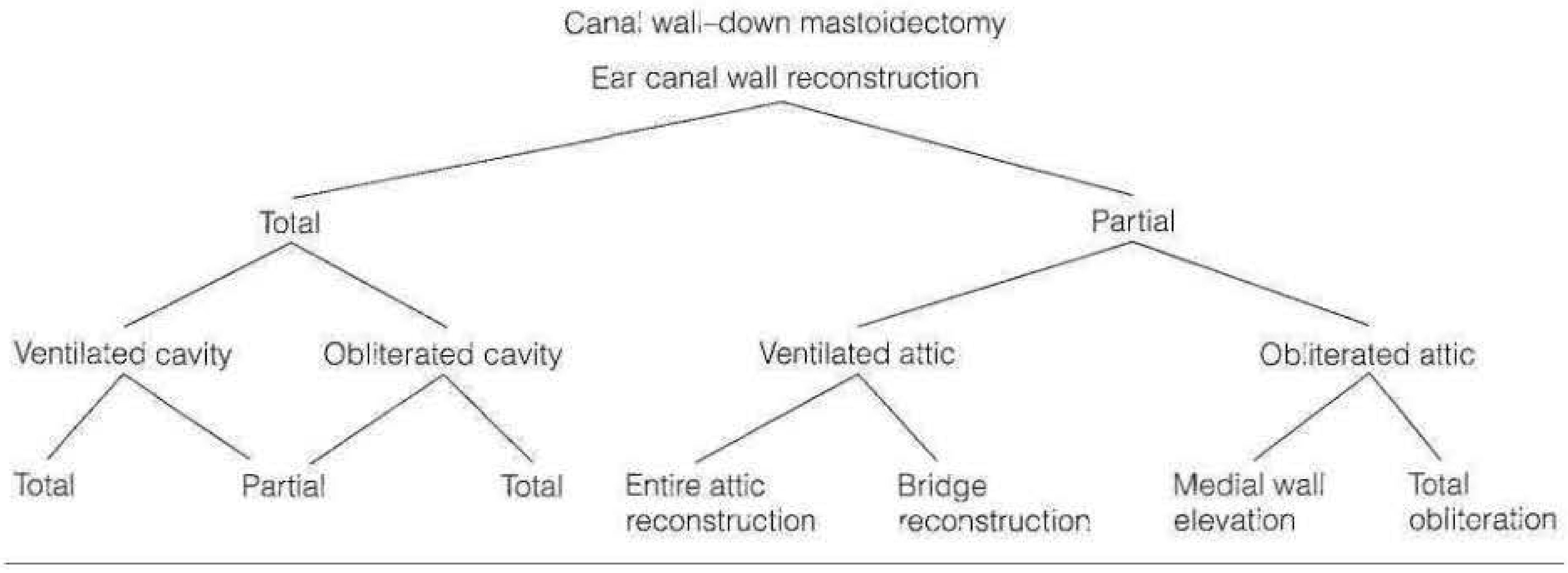
Criteria for Cavity Ventilation

The following criteria should therefore be met if ventilation of the cavity is to be realistically attempted:

1. Tubal function has to be adequate. The Eustachian tube has to be shown to be patent preoperatively, with a positive Valsalva’s maneuver.

2. The mucosal lining of the tympanic cavity must be adequate, providing ventilation through the tympanic sinus, as well as ventilation through the

Table **12** Reconstruction of the posterior ear canal wall after a canal wall–down mastoidectomy



epitympanic recess. A preoperatively adherent drum, indicating preoperative adhesive otitis or tensa retraction cholesteatoma, will rarely result in successful ventilation of the mastoid cavity.

3. The stapes should be present. A columella placed in front of the tympanic isthmus with the possibility of adhesion formation between the columella and the surrounding structures, especially the facial eminence, may obstruct the tympanic isthmus and hamper ventilation of the cavity.

4. There should be at least some mucosal lining of the medial attic wall, allowing rapid mucosal regeneration. This is perhaps the most important criterium, because the mucosa is often removed during cholesteatoma removal. If no mucosa is preserved, it has to regenerate from the tympanic cavity, which takes time. In the meantime, the denuded bone may become covered by granulations, blocking the attic, and causing the formation of adhesions between the attic and the newly formed ear canal wall, which is then pulled posteriorly — a mechanism similar to that seen in the formation of postoperative attic retraction after canal wall–up mastoidectomy (Chapter 8, Fig. **374**).

In addition, mucociliary clearance from the antrum via the attic is eliminated, leading to the accumulation of secretions in the attic.

5. Technically, it should be possible to fix the graft material to the anterosuperior wall of the cavity and to the facial ridge, so that it "hangs" between these two structures, resulting in a wide and stable communication between the mastoid cavity and the tympanic cavity. A low facial ridge, and a large distance between the facial ridge and the anterosuperior wall of the cavity, are thus unsatisfactory conditions. It is best for the bony bridge, or at least part of it, to be present, providing some support for the new ear canal wall and ensuring connection between the drum and the facia.

6. The graft material, preferably autogenous, should be large enough to cover the entire posterior ear canal wall region, i. e., the temporalis muscle fascia should be at least 2×3 cm, with large plates of cartilage or cortical bone. This is not easy to achieve in an ear that has been previously operated on. The methods and problems of harvesting autogenous grafts are described in Vol. 1, Chapter 6.

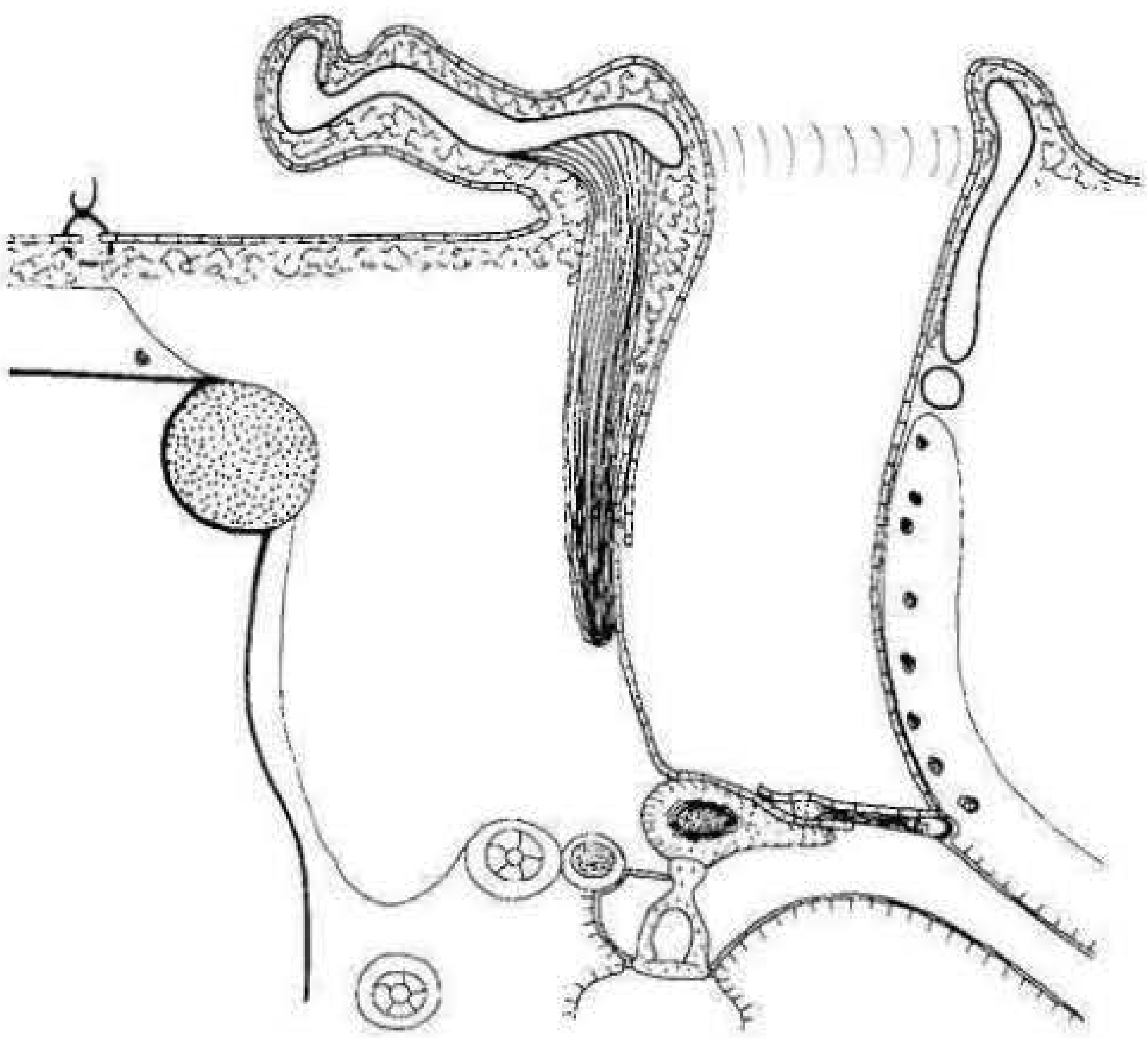


Fig. **814** **Reconstruction of the ear canal with fascia and Palva flap,** in a side view. A large fascia is placed under the drum remnant, covering the interposed incus. It then turns laterally to form the new ear canal. A Palva flap is placed behind the fascia. The epithelial flaps cover the meatal side of the fascia. The cavity is intended to be ventilated

Reconstruction with Fascia

Retroauricular Approach, with Palva Flap

Reconstruction with a Palva flap is possible only via the retroauricular approach. Reconstruction with temporalis muscle fascia is the basic method, with the fascia used to cover other grafts in combined-graft reconstructions. The principle is to create a tight connection between the drum medially, the bony wall superiorly, the facial ridge inferiorly, and the meatal soft tissues laterally (Fig. **814**). In addition, canal skin flaps must be placed on the meatal aspect of the fascia, and although theoretically this is easy to achieve, practically it is far more complicated, mainly because any pressure on the fascia must be avoided in order to maintain the opening between the tympanic cavity and keep the attic open to ventilate the cavity. For the same reason, any support for the fascia from the attic or from the cavity. e. g., by filling the cavity with Gelfoam balls, is not desirable, since this may obstruct the attic. However, sometimes this can not be avoided.

After ossiculoplasty and preparation of the ear canal skin flaps used to cover the fascia, a few Gelfoam balls are placed in the attic temporarily to maintain the space for ventilation, as well as to support the fascia (Fig. **815**). A 2×3–cm semi-dry and malleable sheet of fascia is placed onto the cavity walls and into the tympanic cavity. Semi-dry fascia is the easiest to handle during placement under the drum remnant; dry fascia has to become softer and malleable in order to be manipulated. The fascia is carefully adapted to the undersurface of the drum

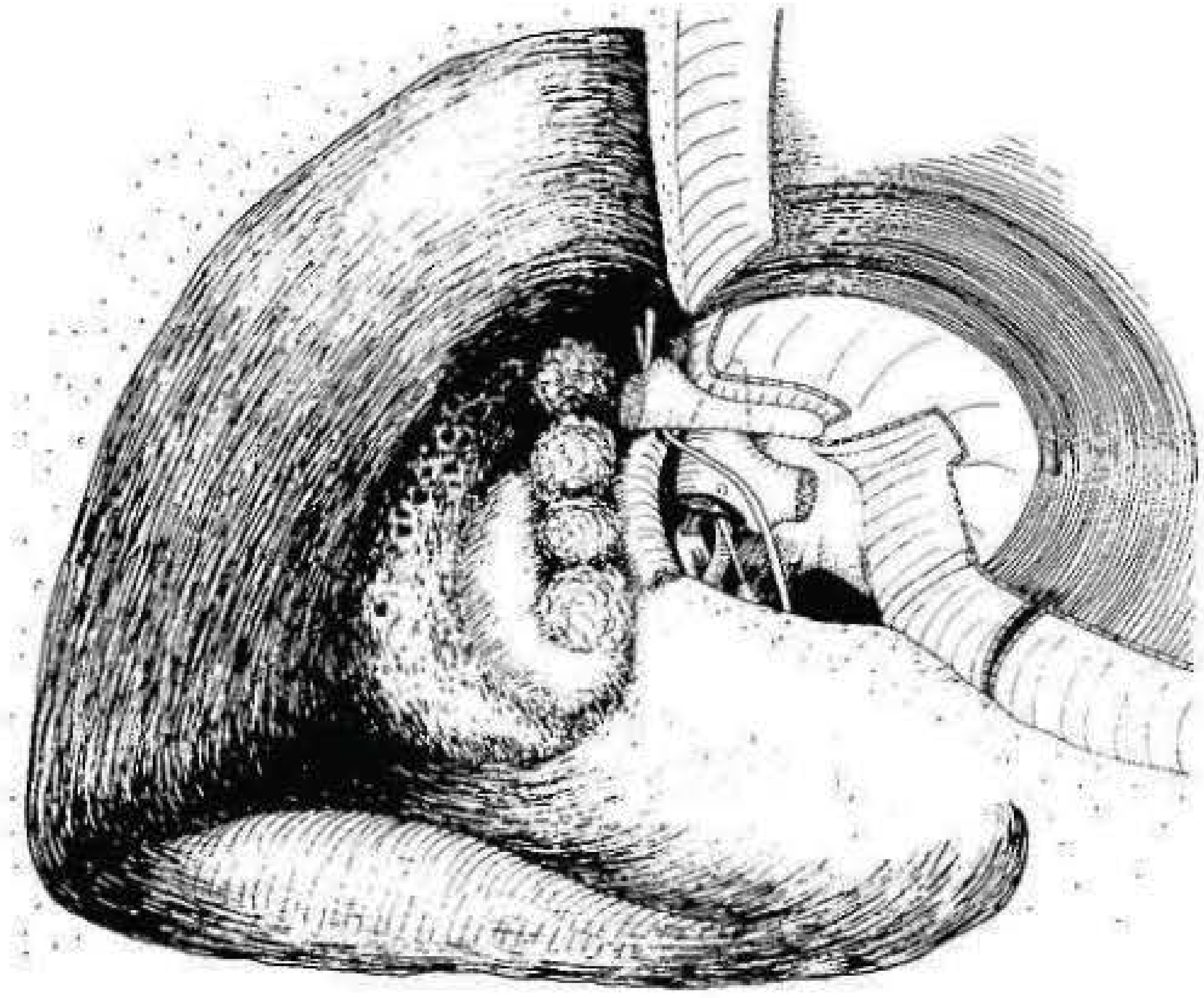


Fig. **815** **A canal wall–down mastoidectomy cavity with low facial ridge, prepared for reconstruction and ventilation.** The stapes is present, the incus is interposed, the epithelial flaps are elevated, and Gelfoam balls have been temporarily placed in the attic to support the fascia during reconstruction. They are removed after fixation of the fascia to the bone

(Fig. **816**). The epithelial flaps are replaced, fixing the fascia (Fig. **817**), and the flaps are then fixed with Gelfoam balls. The Gelfoam is initially placed over the region of the bridge, to secure a connection between the fascia and the interposed incus (Fig. **818**) and also to avoid lateralization of the fascia in this region. The ear canal is gradually packed with Gelfoam and small pieces of gauze moistened with cortisone and Terramycin ointment (Fig. **819**), while the fascia is still being carefully adapted to the remaining bony structure of the ear canal. After the ear canal is packed, the fascia is gently pulled laterally and adapted to the canal wall, bringing it as far laterally as possible, so that the posterior ear canal skin flap can cover it from the meatal side (Fig. **820**). Communication between the tympanic cavity and the mastoid cavity is thus secured, allowing removal of the Gelfoam balls from the attic region.

The self-retaining retractor that held the auricle anteriorly during the retroauricular approach, is now removed. The previously prepared Palva flap is gradually pushed into the cavity, strengthening the posterior canal wall as the auricle is replaced in its original position (Fig. **821**). Some further packing of the ear canal is required, but this should not be too firm in order to avoid displacement of the fascia posteriorly. The auricle is placed in its proper position (Fig. **814**), and the postauricular wound is sutured.

The ear canal pack is not touched until three weeks after the operation, when is it removed. The patient is asked to perform the Valsalva maneuver from the fourteenth postoperative day, as long as the

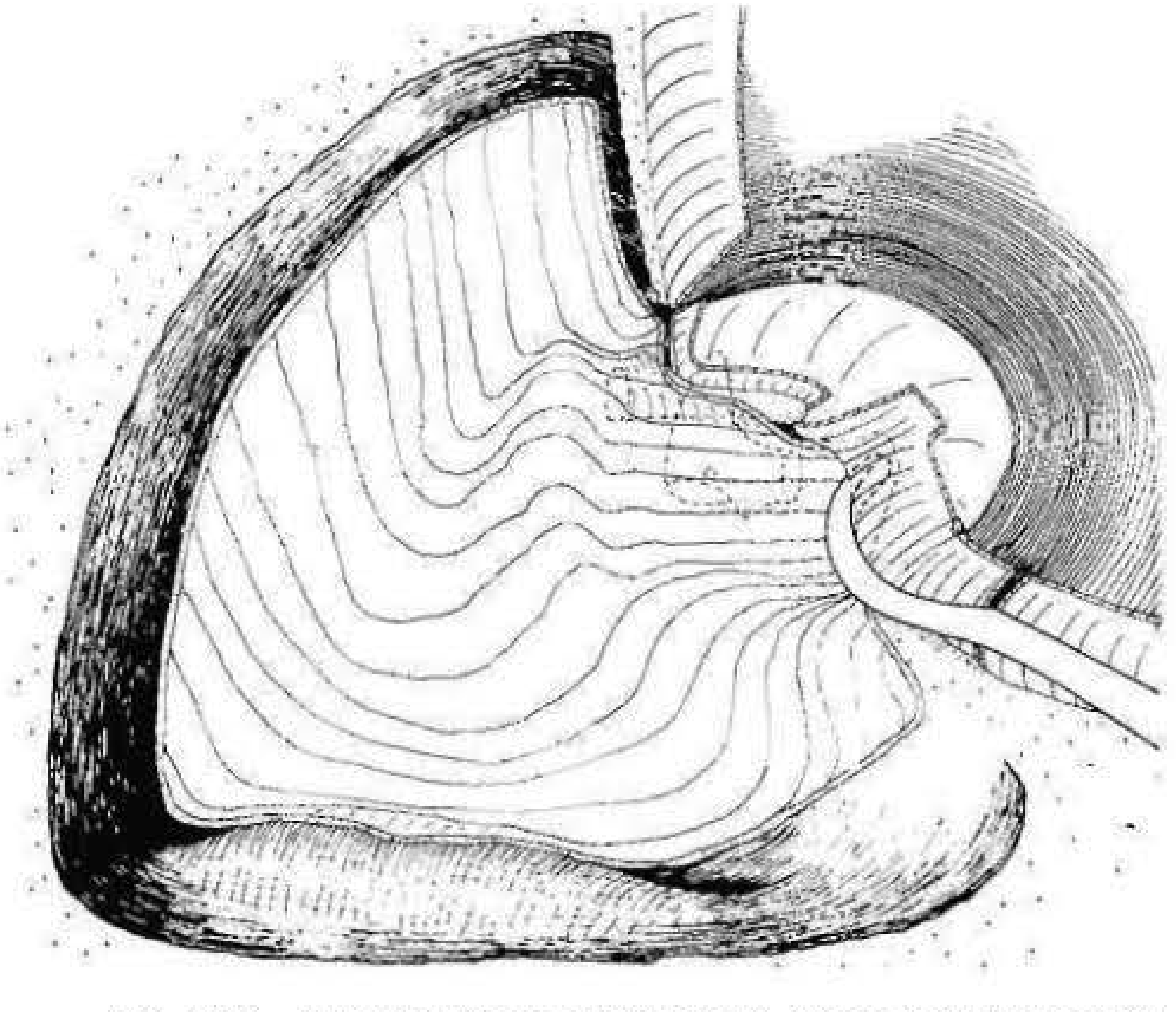


Fig. **816** A large piece of fascia is placed on the cavity walls. It is adapted to the drum remnant as an underlay graft, both anteriorly and posteriorly

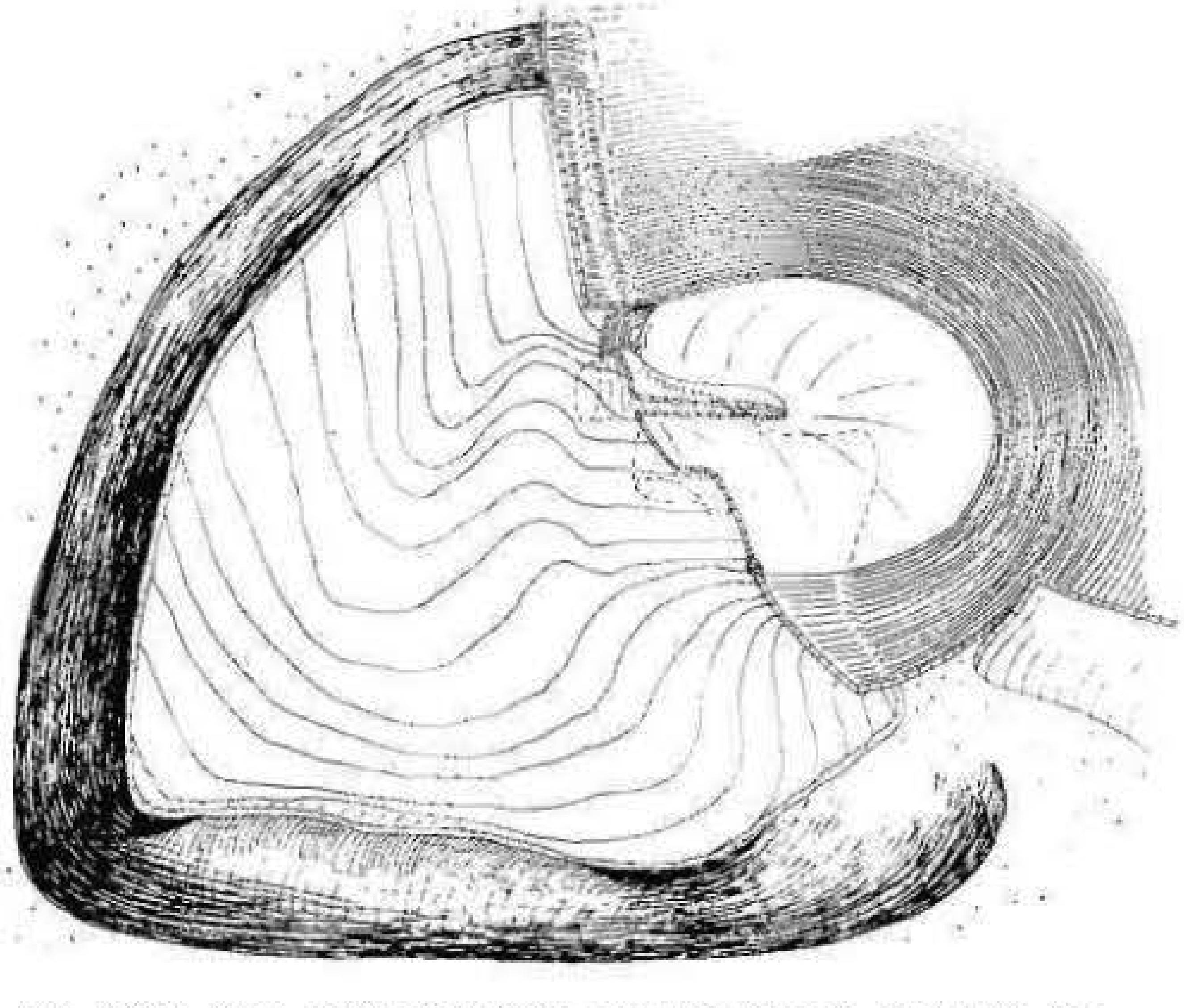


Fig. **817** The epithelial flaps are replaced, and will be fixed with Gelfoam balls. The fascia will be turned laterally to form the ear canal

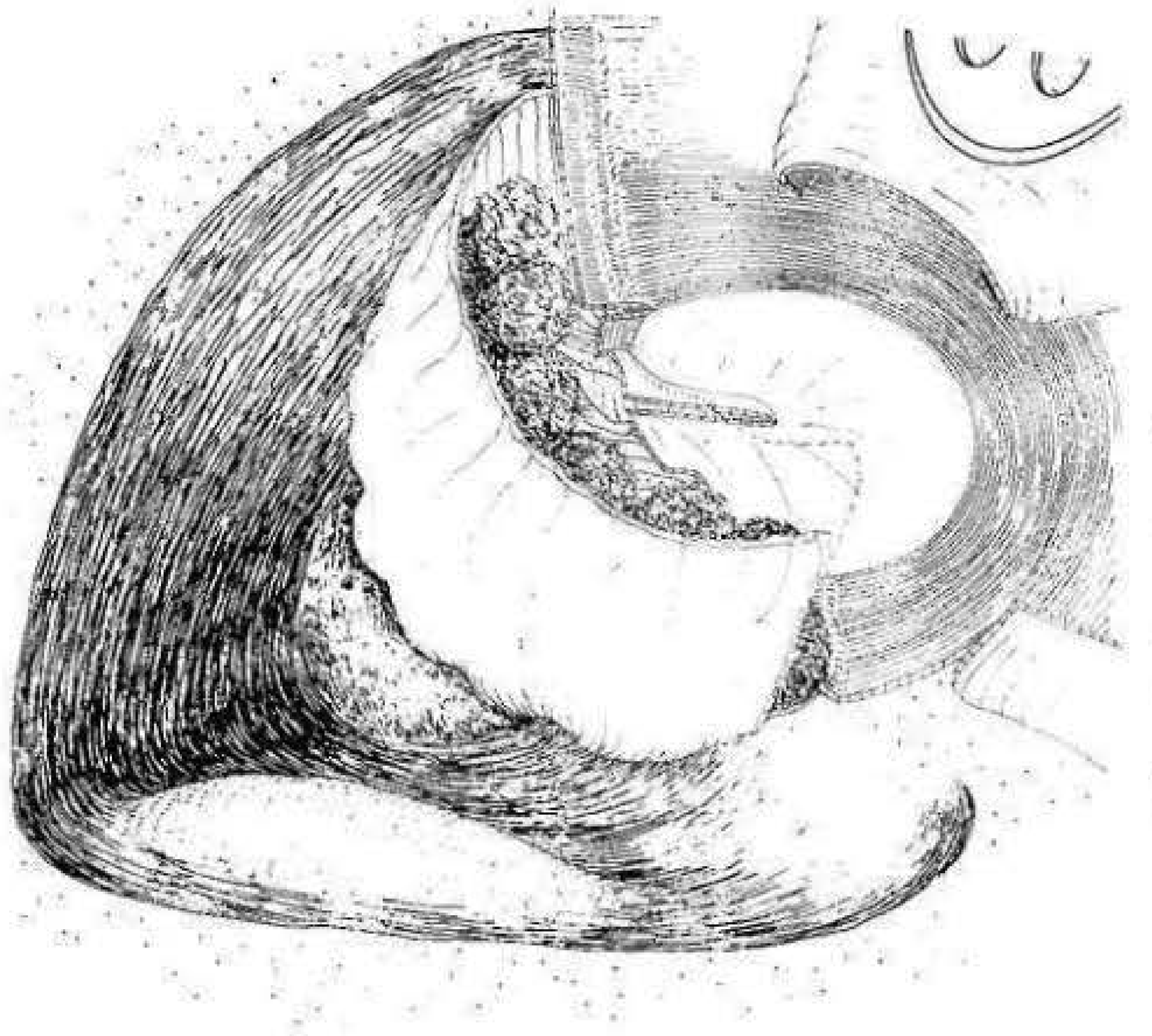


Fig. **818** The fascia has been turned laterally, and the ear canal is gently packed with Gelfoam balls to maintain the upper part of the ear canal and secure contact to the incus

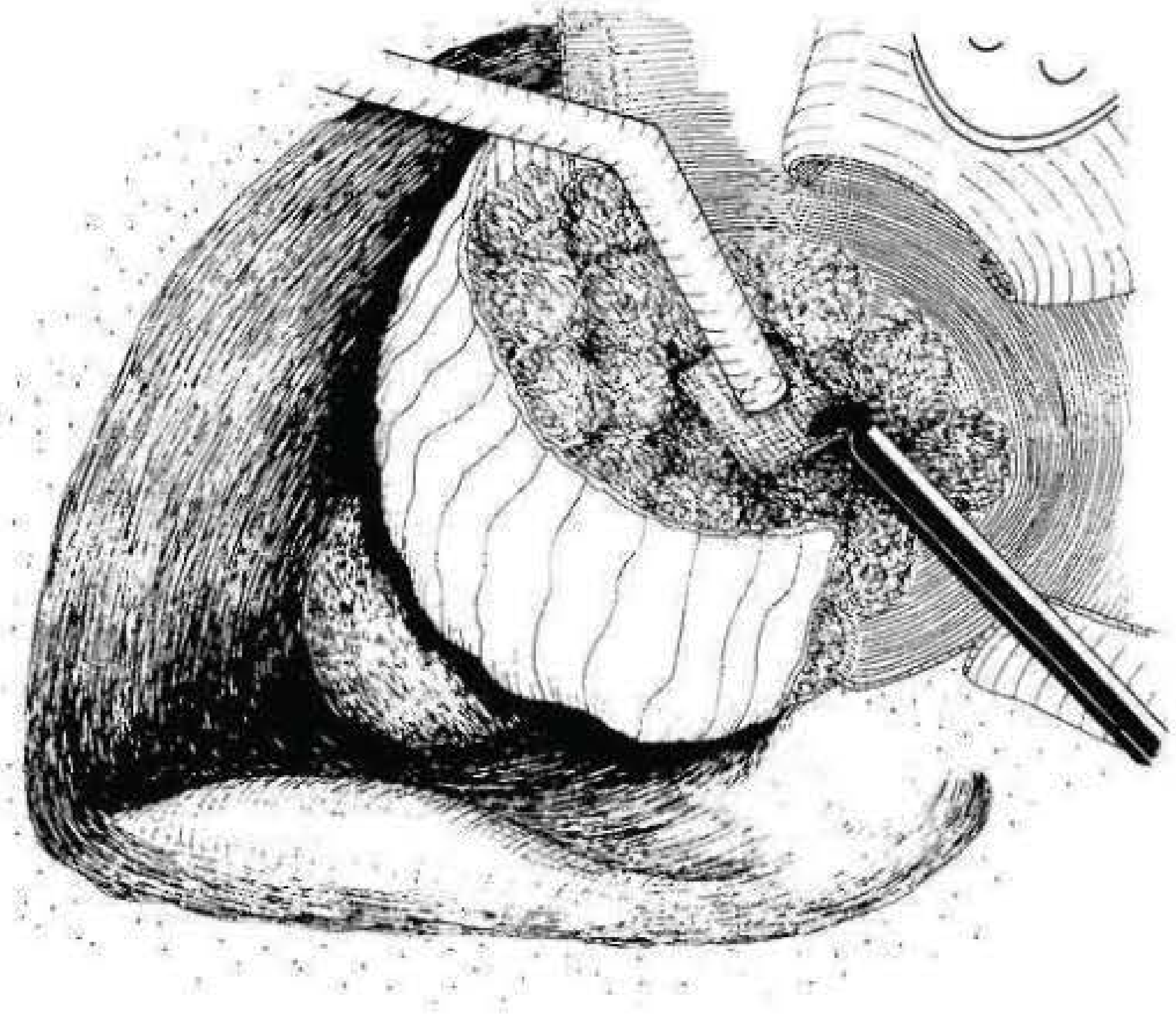


Fig. **819** Further packing of the ear canal and adaptation of the fascia to the superoanterior wall of the cavity and the facial ridge

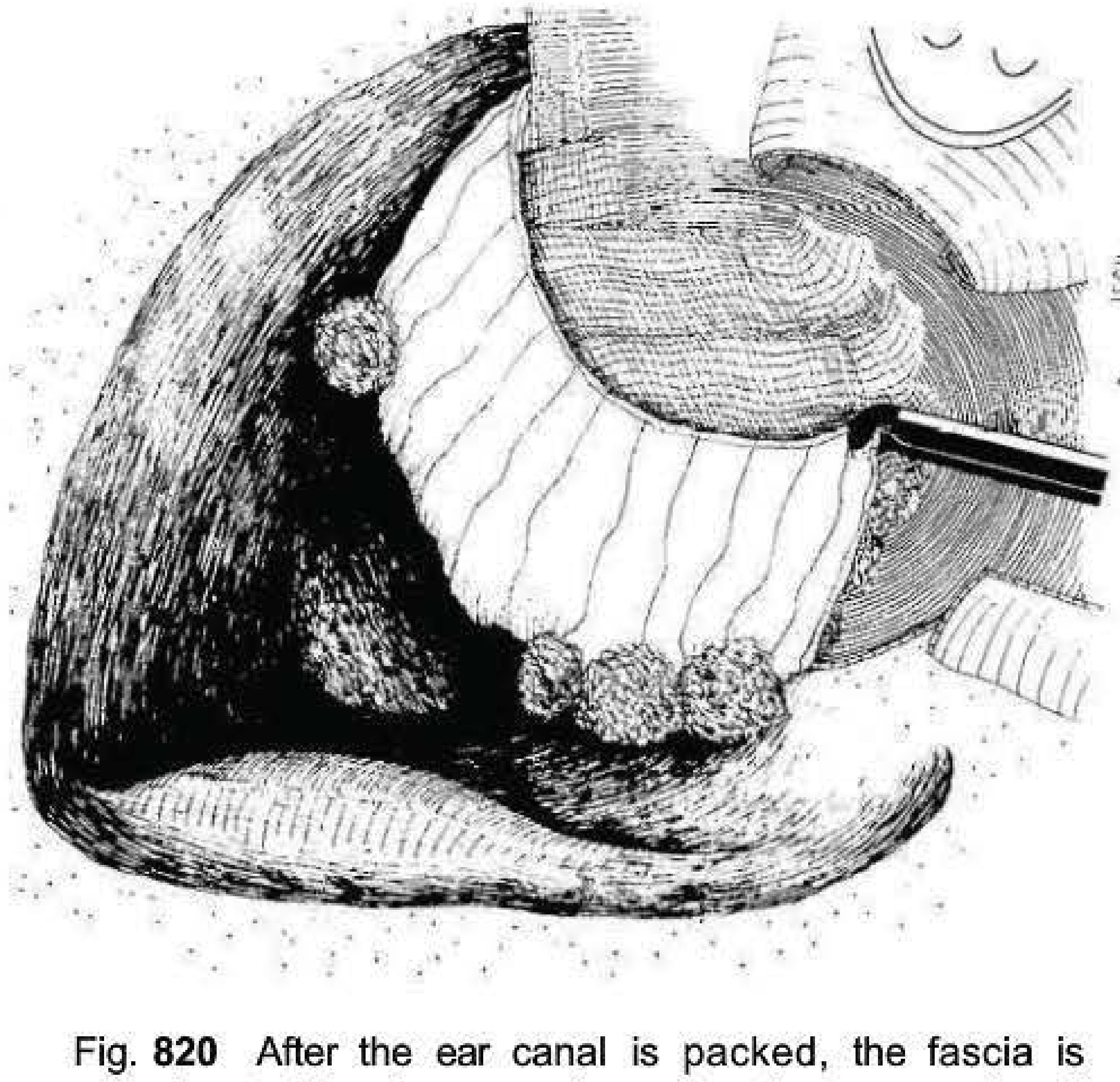


Fig. **820** After the ear canal is packed, the fascia is pulled out with a forceps, elongating the ear canal wall and further adapting the fascia. The reconstructed ear canal wall is now ready to be strengthened with a Palva flap

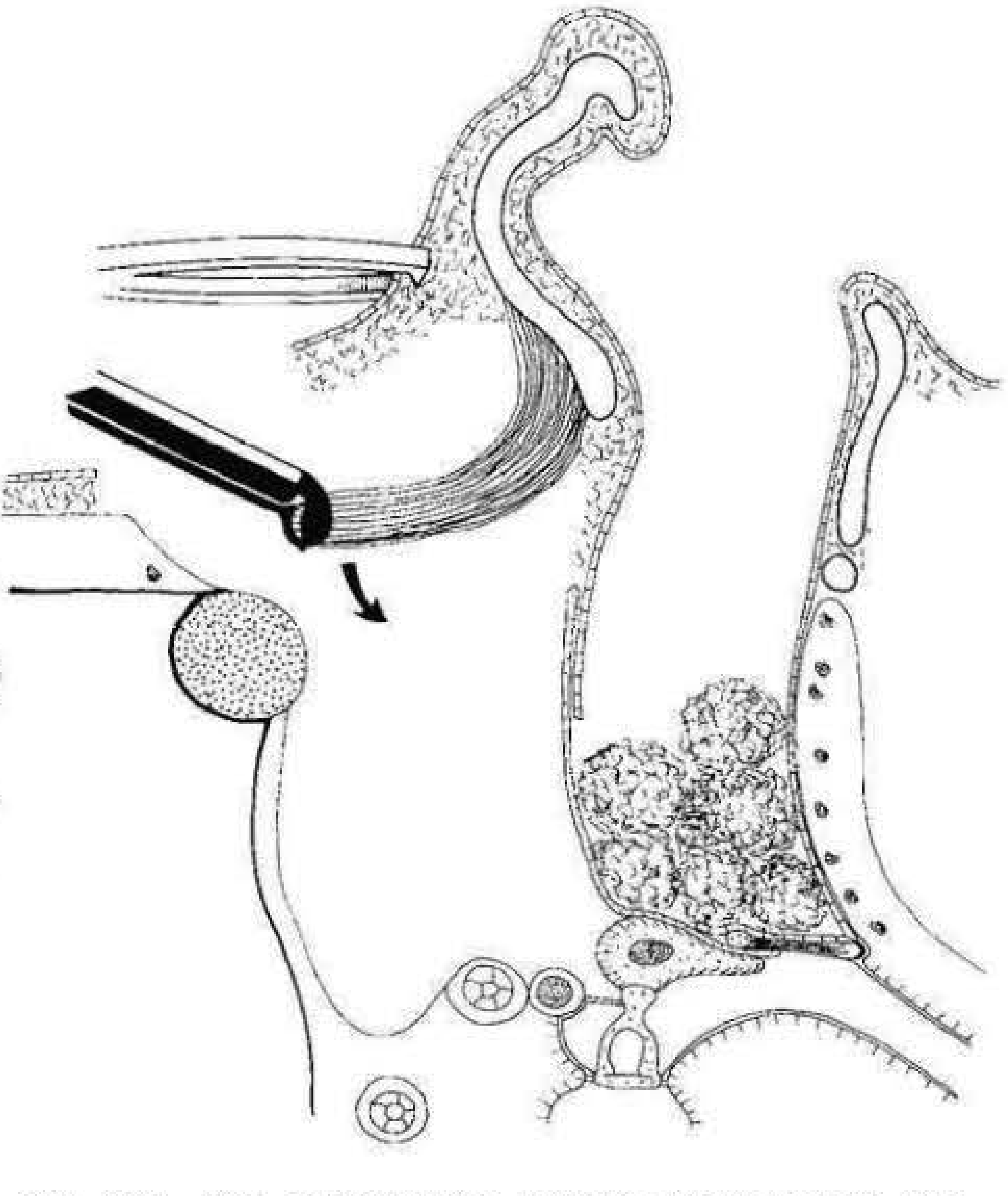


Fig. **821** The self-retaining retractor is removed. The Palva flap, prepared at the beginning of the procedure, is freed and brought down (arrow) onto the posterior aspects of the fascia, while the auricle is replaced in its original position. The ear canal will be packed with Gelfoam balls and a gauze strip moistened with oxytetracycline and hydrocortisone ointment (Terra-Cortril) for three weeks

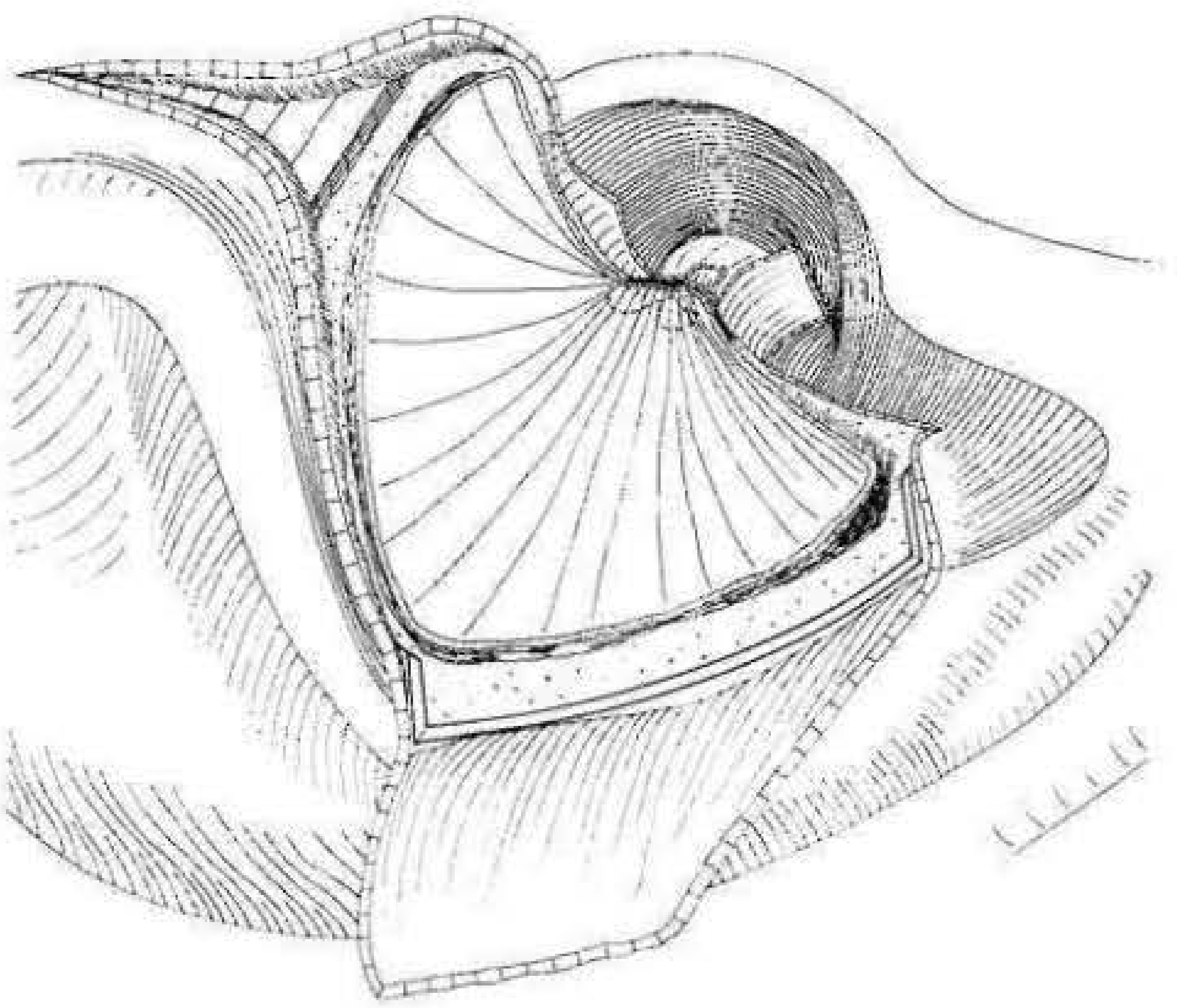


Fig. **822** **Reconstruction of the ear canal wall in an endaural approach.** After ossiculoplasty with an incus interposed between the malleus handle and the stapes, a large piece of fascia is placed under the edges of the posterior perforation as an underlay graft. Fascia covers the facial ridge and the superoanterior and posterior edges of the cavity. A small Körner meatoplasty, with resection of a strip of conchal cartilage, is performed

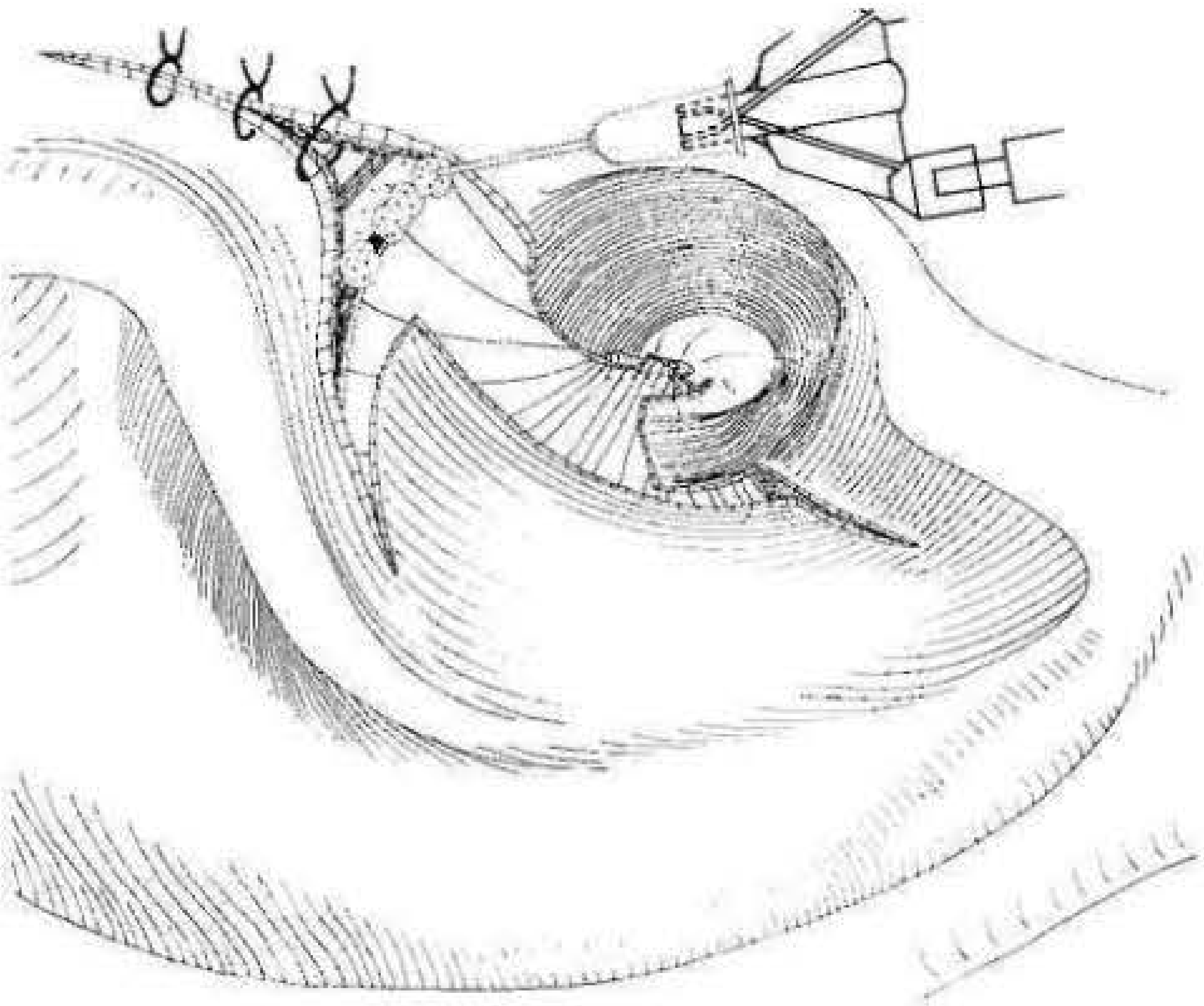


Fig. **823** The epithelial flaps are replaced; first, the tympanomeatal flap, and then the superior and the lateral flaps, fixing the fascia. The fascia is laterally fixed with fibrin glue placed between the bone and the fascia

Valsalva is positive preoperatively; if not, he or she should start after one week. The final situation after a successful operation resembles Figure **814.**

One to six years after reconstruction of the ear canal wall using a Palva flap in 12 prognostically favorable ears with old radical cavities, 19% were dry, and 66% had a ventilated cavity (Tos 1977).

Smith et al. (1986) performed canal wall reconstruction using a large piece of fascia and a Palva flap, totally obliterating the cavity behind the flap with Gelfoam, with relatively good results: of 30 patients operated upon, the reconstructed ear canal wall was intact in 53% of cases two years postoperatively, and was within the position normally occupied by the bony posterior canal wall. In the remainder, a variable degree of retraction of the membranous posterior canal wall was noted. This indicates that a significant amount of Gelfoam can be placed in the cavity.

This reconstruction of the ear canal is an important element of several obliteration techniques.

Endaural Approach

Reconstruction of the ear canal using fascia in the endaural approach after a canal wall–down mastoidectomy is technically much easier than in the retroauricular approach. After canal wall–down mastoidectomy and after ossiculoplasty, a large piece of fascia is placed as an underlay graft to cover the perforation (Fig. **822**). The fascia covers the facial ridge laterally, and is then placed over the posterior edge of the cavity and laterally over the mastoid tegmen. The canal skin flaps are replaced superiorly, carefully fixing the fascia. The laterally based ear canal skin flap (Körner flap) is pulled back, covering as much of the fascia as possible, and sutures are placed, partially closing the Heermann B incision. The fascia is fixed in position with Gelfoam balls. Some surgeons fix the fascia with fibrin glue (Pannis et al. 1979) placed at the junction between the bone and the fascia, preferably under the fascia (Fig. **823**). In the endaural approach, however, the ear canal wall is not strengthened with a Palva flap, which cannot be harvested.

It is wise to perform a Körner meatoplasty with resection of conchal cartilage (Fig. **822**) in case of future retraction of the fascia, which often occurs, resulting in an open cavity situation.

Reconstruction with Autogenous Cartilage

In total reconstruction of the ear canal wall, autogenous tragal cartilage, allogenous septal cartilage, and allogenous knee cartilage have been used. In contrast to scutumplasty, large pieces of cartilage are needed to reconstruct the entire ear canal wall.

Tragal Cartilage

Even though tragal and conchal cartilage are the most commonly used graft materials in scutumplasty (Chapter 6, Figs. **349–359**), only small series have been published using tragal cartilage.

Endaural approach. Eviatar (1978) reconstructed the ear canal wall in ten cases using tragal cartilage and perichondrium after conservative radical surgery. In the endaural approach, the canal skin is elevated and widely preserved (Fig. **824**). A compound cartilage–perichondrium graft, with the perichondrium partially elevated from one side, is placed in the original position of the ear canal wall, in contact with the head of the malleus. The perichondrium is then placed as an underlay graft under the drum remnant, closing the perforation (Fig. **825**). The skin flaps are replaced, and the ear canal is thus partially reconstructed. Laterally, there is still a defect that needs to be covered (Fig. **826**). In Eviatar's method, it is evident that the tragal cartilage cannot reach from the superior to the inferior cavity wall, and additional tissue, e. g., a large piece of fascia, is required to cover the defect between the tragal cartilage and the facial ridge.

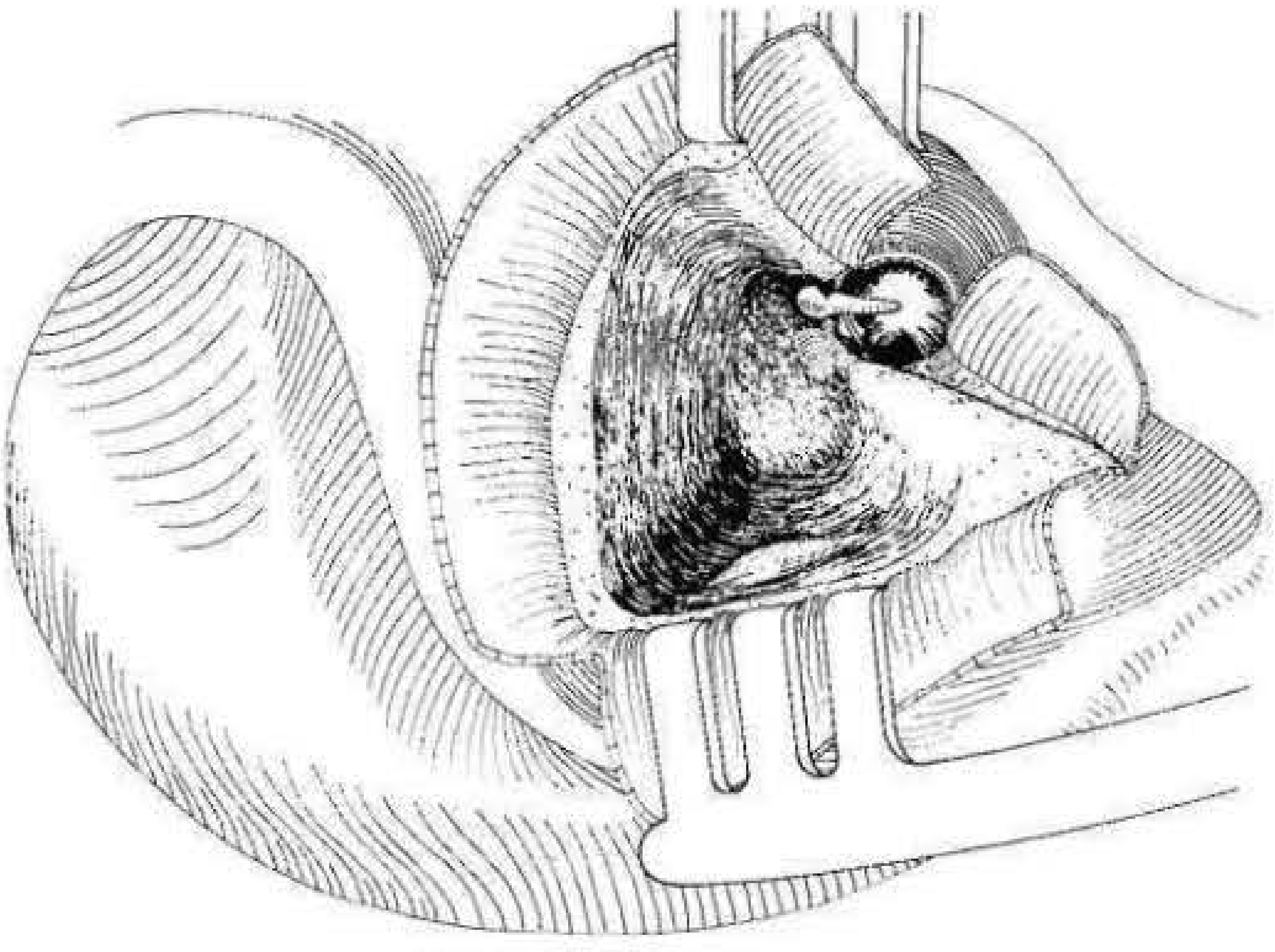


Fig. **824** **Ear canal wall reconstruction with tragal cartilage** (Eviatar). In the endaural approach, the epithelial lining of the canal wall–down cavity is elevated, and large skin flaps are created: inferior, anterior, lateral, and posterior

Retroauricular approach. The present author has used tragal cartilage as a compound graft in reconstruction of the ear canal wall when performing obliteration of old radical cavities (Tos 1977, Siim and Tos 1987), but in some cases the author has reconstructed the ear canal with tragal cartilage in order to ventilate the cavity in the following way: A tragal cartilage of maximum size is harvested, and the perichondrium is elevated from the concave meatal side, so that perichondrium is still connected to both edges of the tragal cartilage (Fig. **827**). This perichondrium fixes the tragal cartilage to the

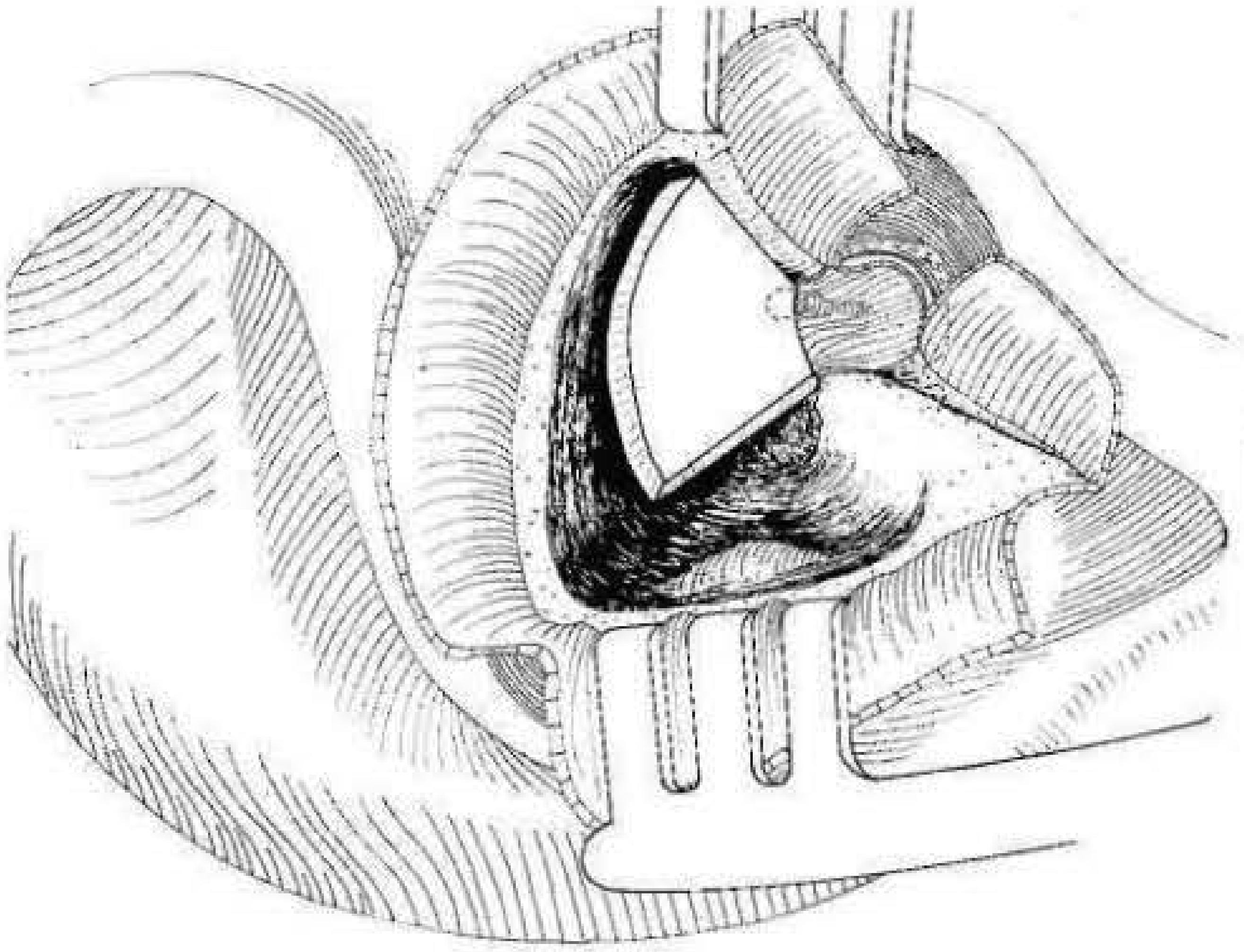


Fig. **825** A compound graft of tragal cartilage is placed at the side of the ear canal. The perichondrium, attached to the edge of the cartilage, covers the total perforation as an underlay graft

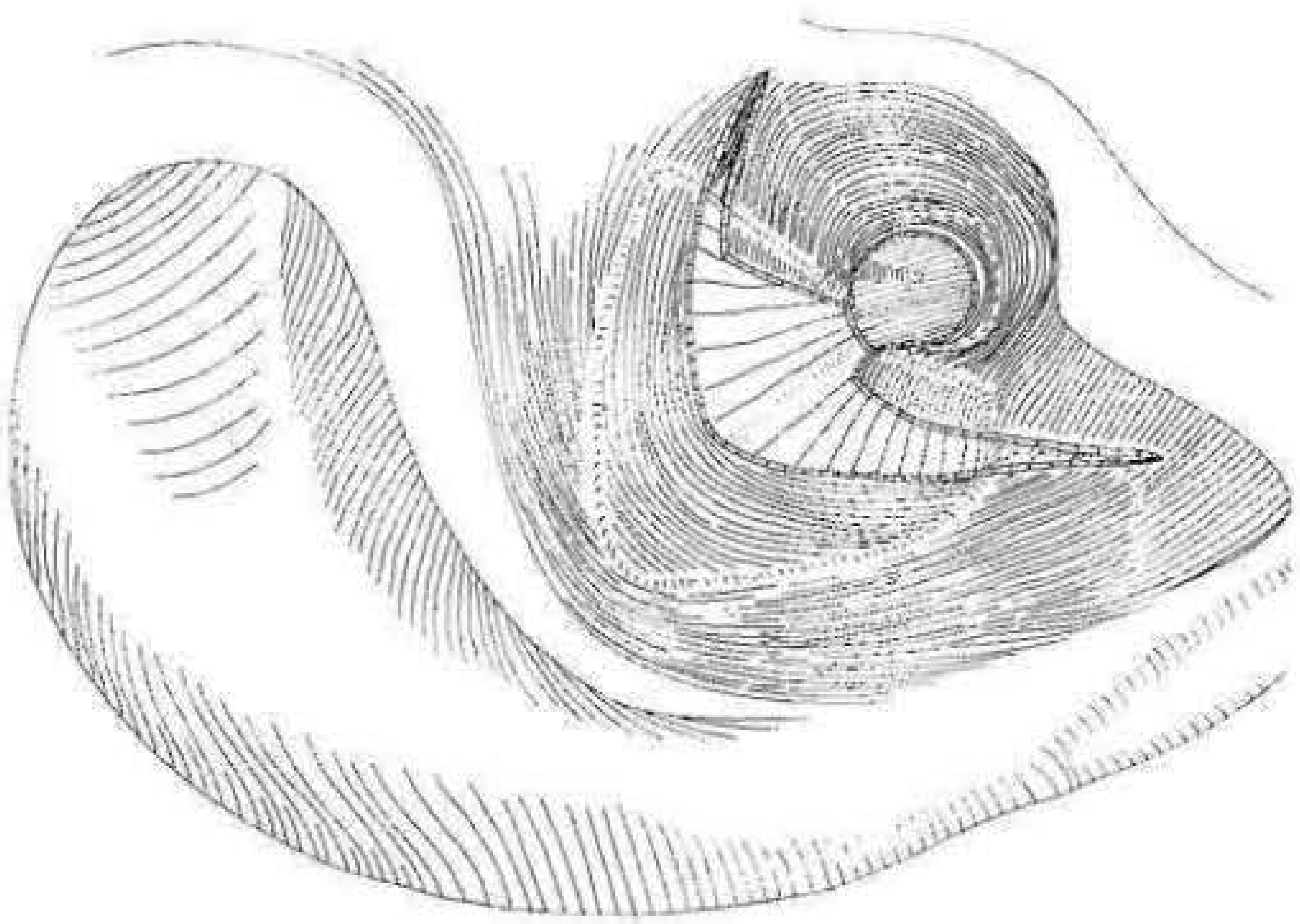


Fig. **826** The epithelial flaps are replaced, securing the position of the tragal cartilage

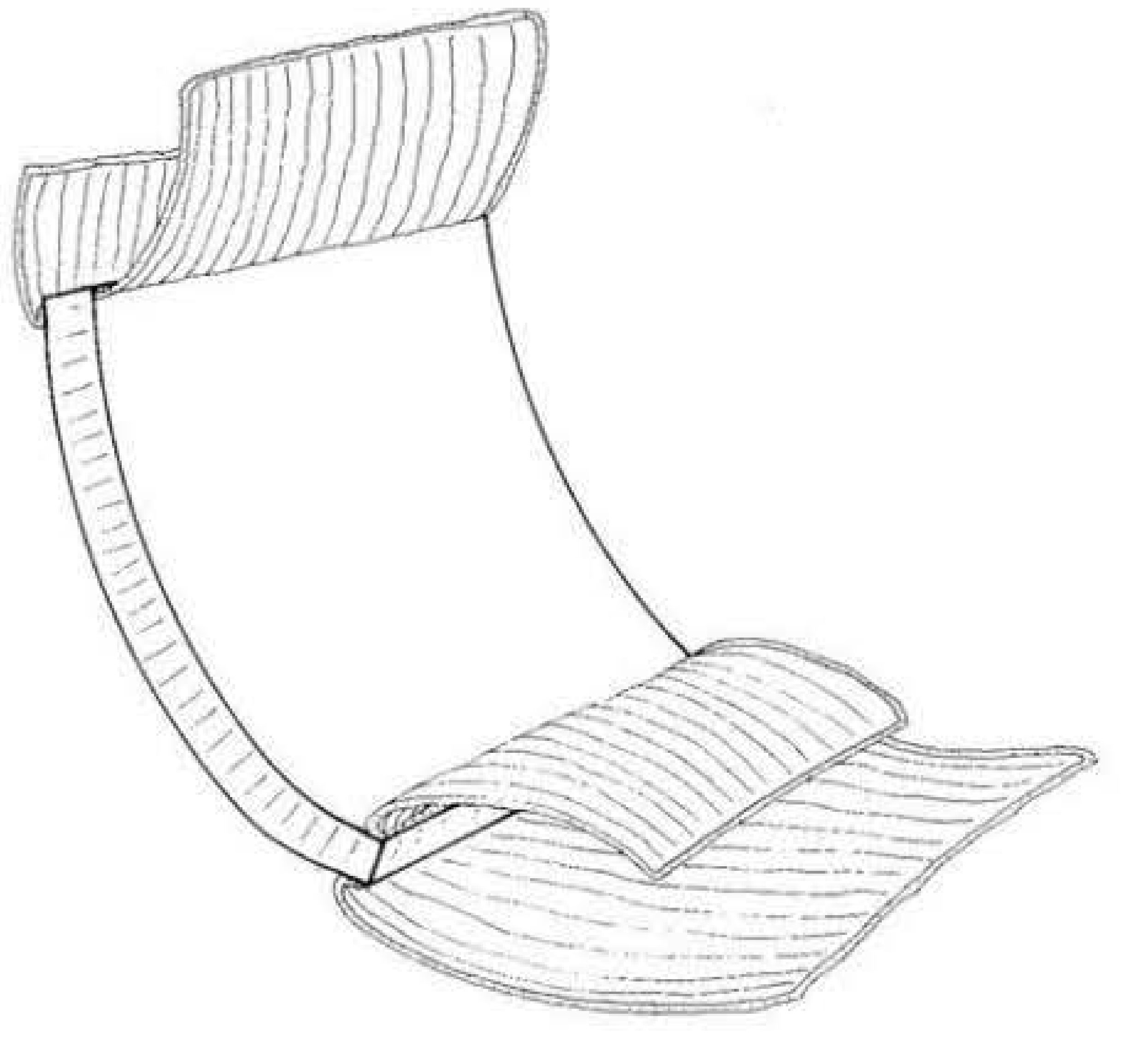


Fig. **827** **Retroauricular reconstruction of the ear canal wall with a compound tragal cartilage–perichondrium graft** (Tos 1977). The elevated perichondrium from the concave side of the cartilage is placed on the meatal aspects of the bone. On the convex side, a large perichondrium flap is elevated and placed on the mastoid aspect at the facial ridge. Superiorly, a small flap of the perichondrium is also elevated

meatal side of the remaining ear canal wall and cavity wall. Perichondrial flaps are similarly elevated, from the outer aspect of the tragus, and are used to fix the cartilage inferiorly onto the mastoid side of the facial ridge and to the cavity wall (Figs. **827**, **828**). After the tragal cartilage has been placed between the facial ridge and the anterosuperior wall of the cavity, and after perichondrial flaps have been placed and adapted onto the meatal sides of the ear canal, the perichondrium fixes the tragal cartilage to the mastoid side of the facial ridge (Fig. **829**). Fascia covers the drum perforation and the entire ear canal wall. The epithelial flaps are replaced (Fig. **830**), and the upper edge of the tragal cartilage is further secured by placing a small Palva flap into the cavity (Fig. **831**).

In the present author's opinion, this method of reconstructing the ear canal wall using autogenous cartilage, Palva flap, and fascia (Fig. **831**) is an important element of several obliteration techniques, and can be applied to cover all allogenous material, even autogenous bone.

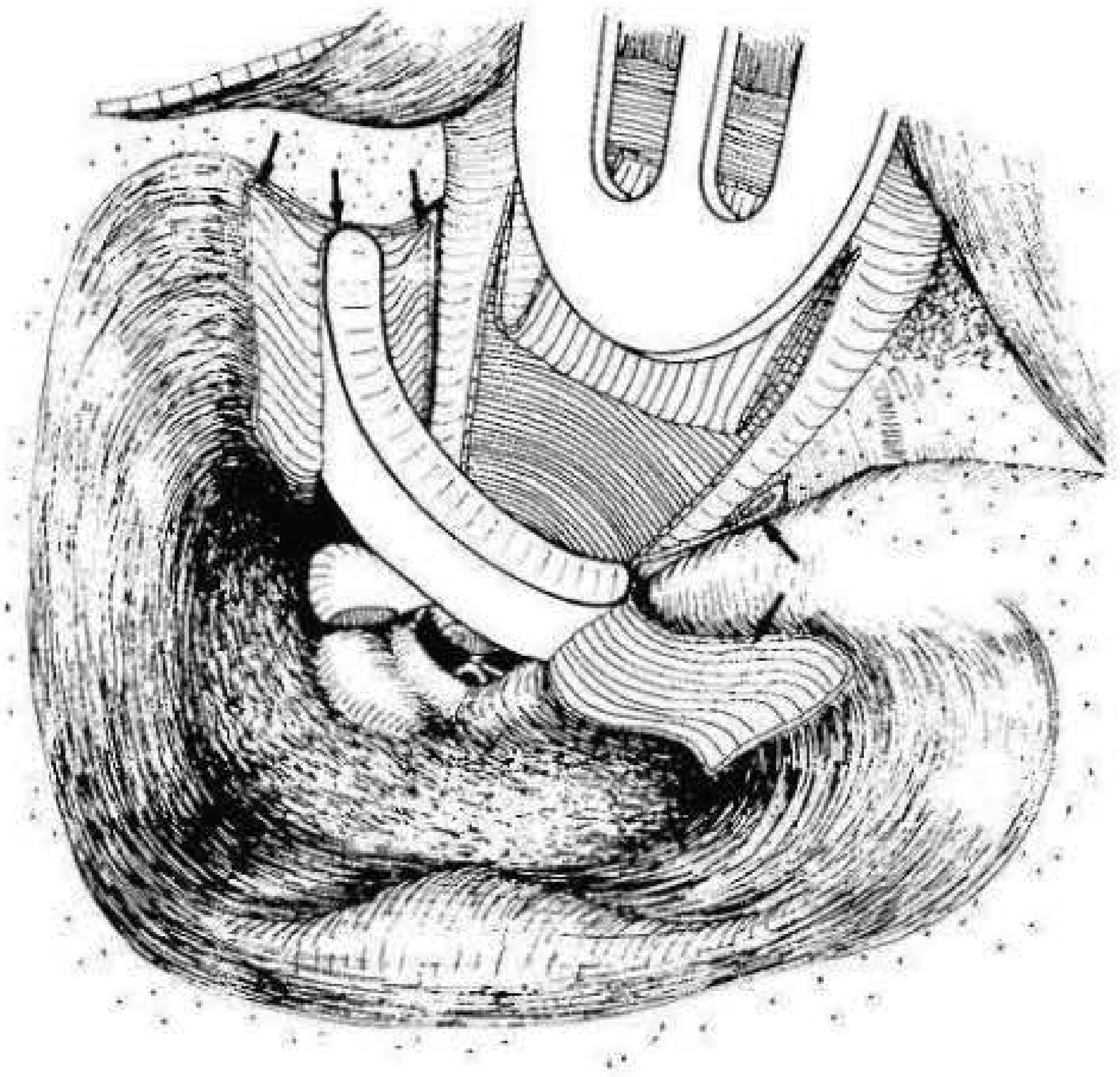


Fig. **828** The tragal cartilage–perichondrium compound graft in position. The cartilage is in contact with the superior wall of the cavity, and is fixed to it by the perichondrium flaps (arrows). Inferiorly, the cartilage has some contact with the facial ridge, and is fixed to its meatal and mastoid sides with the perichondrium flaps (arrows)

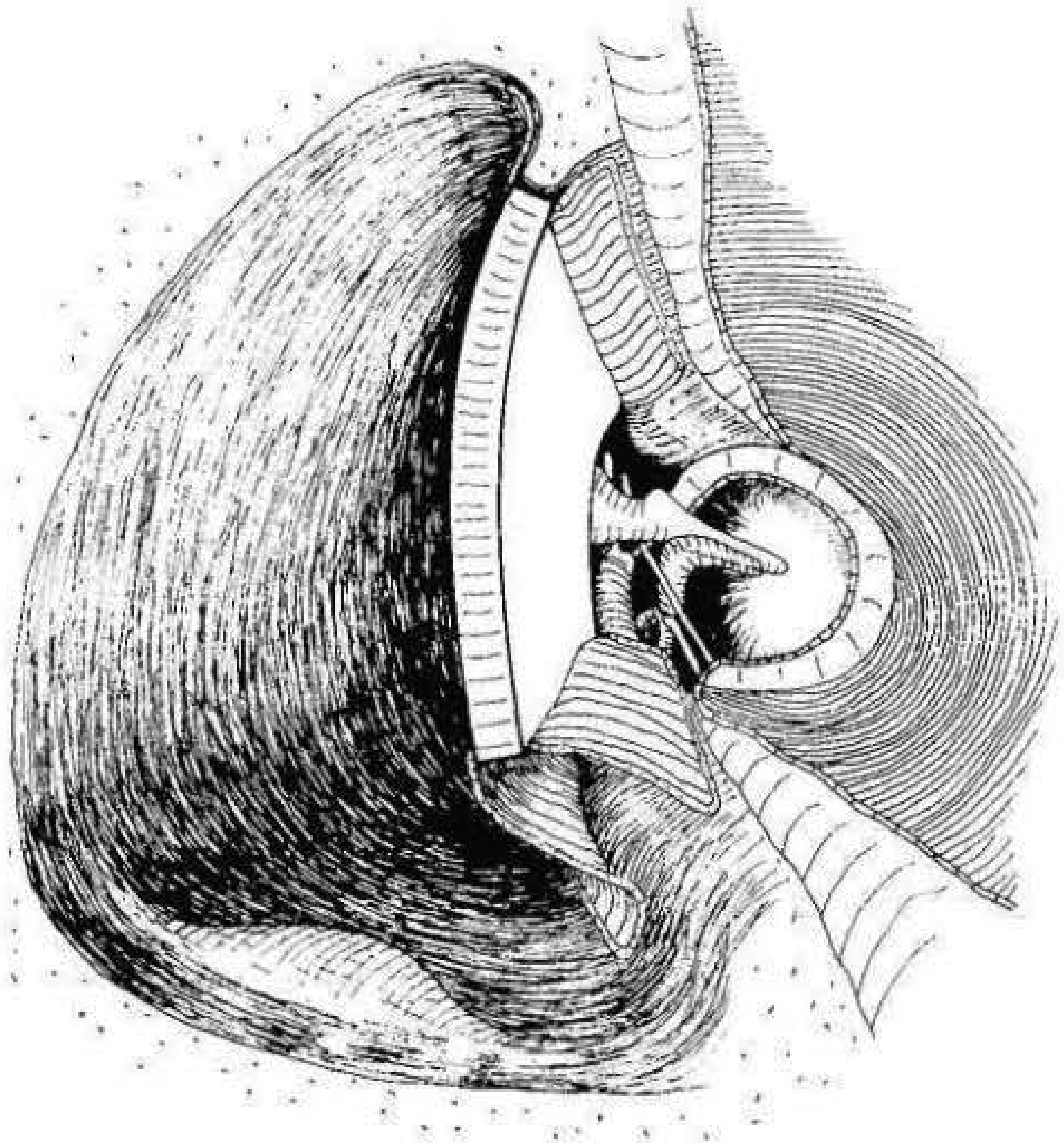


Fig. **829** The cartilage–perichondrium compound graft in position. The perichondrium flaps lie on the meatal side of the ear canal wall superiorly, and on the facial ridge inferiorly. An incus is placed on the stapes and along the malleus handle

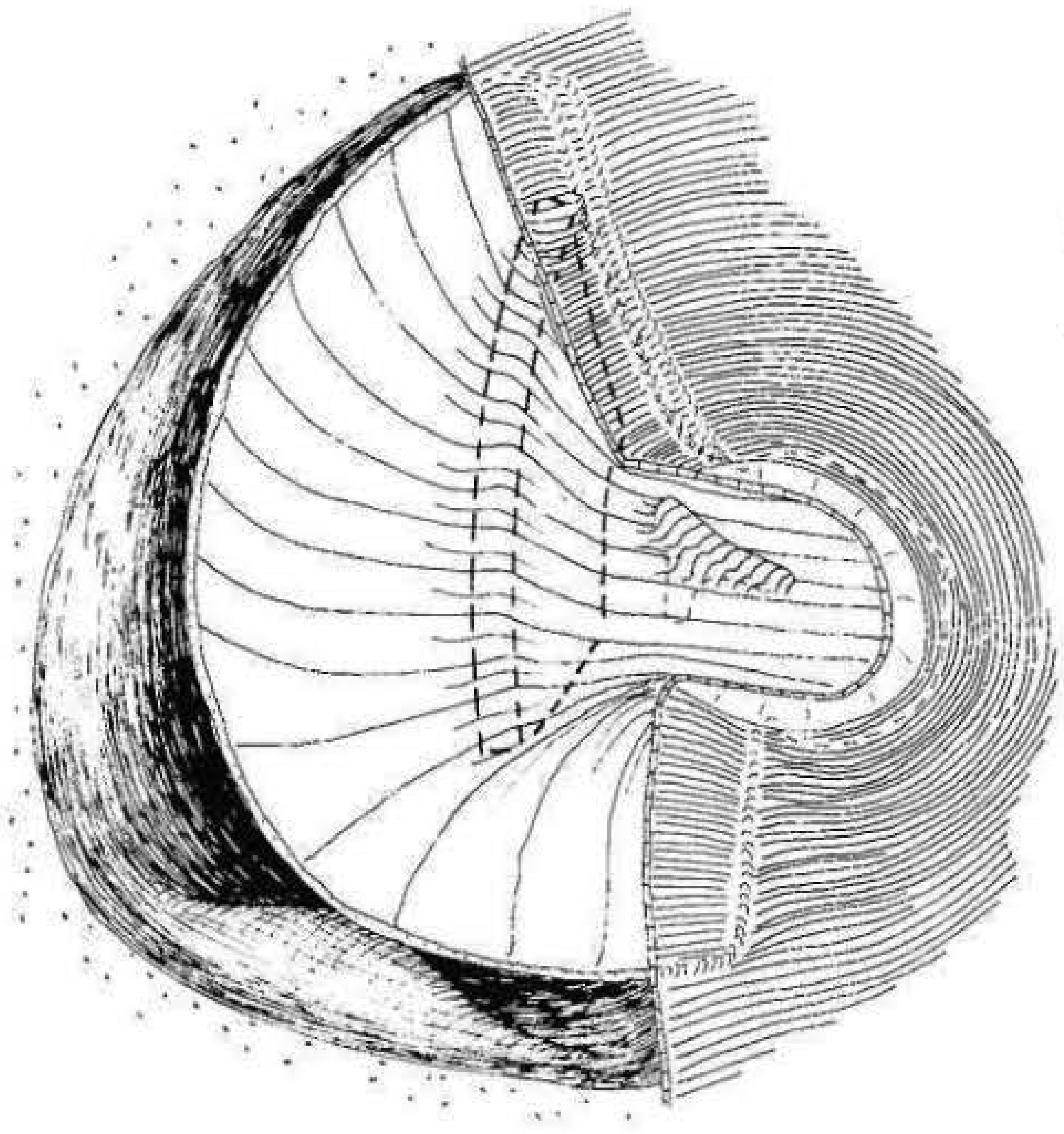


Fig. **830** The new ear canal wall is covered with a large piece of fascia, placed as an underlay graft under the drum remnant, and the epithelial skin flaps are replaced

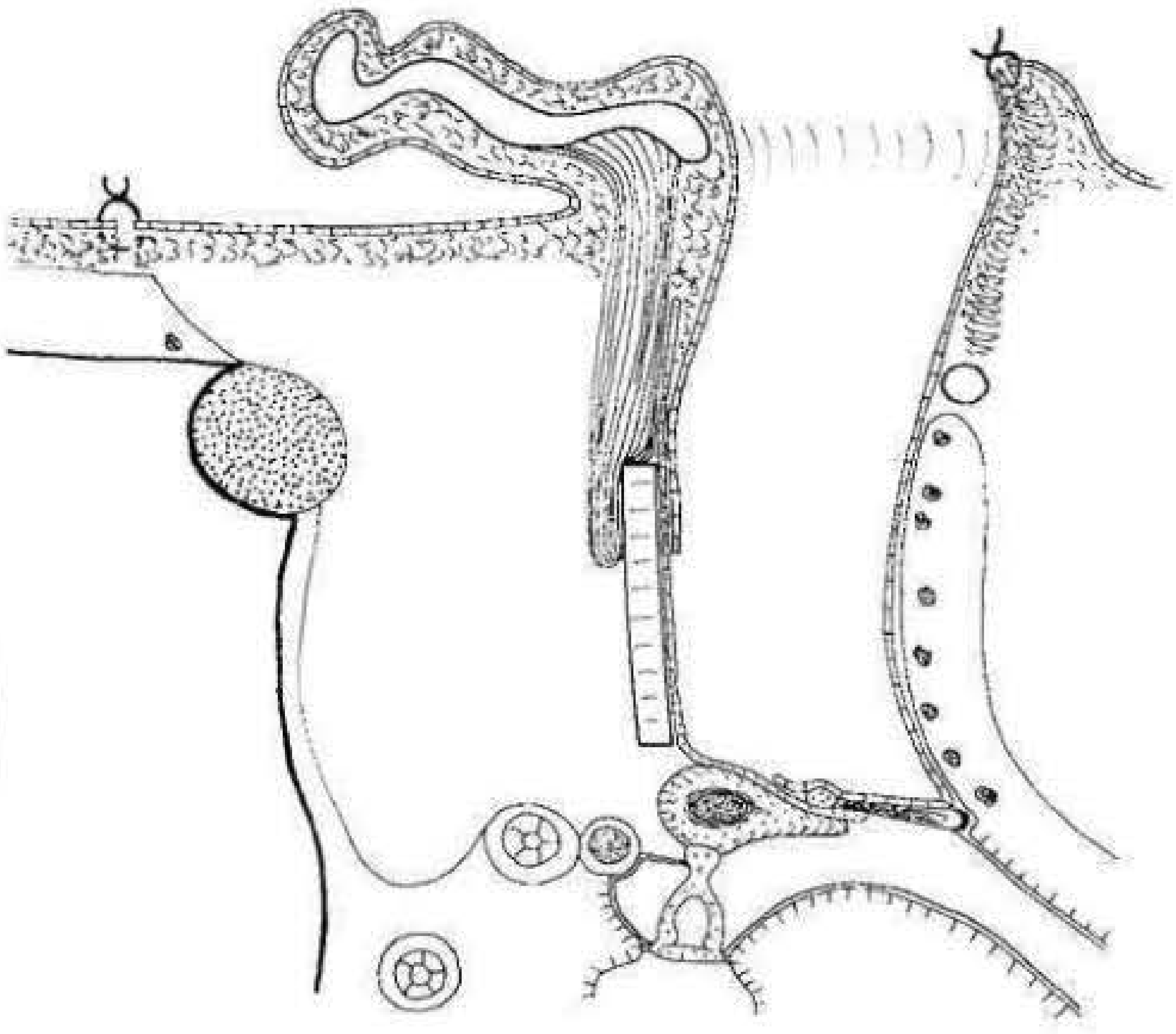


Fig. **831** Side view of the present author's reconstruction of the ear canal. The tragal cartilage lies behind the fascia and anterior to the Palva flap

Reconstruction with Allogenous Cartilage

Reconstruction of the ear canal wall is also performed using allogenous septal or knee cartilage.

Septal Cartilage

Smyth and Dowe (1971) introduced allogenous septal cartilage as a method of reconstructing the ear canal wall in order to ventilate the cavity. An appropriately sized piece of allogenous septal cartilage, preserved in 70% alcohol for two to six weeks, is cut and shaped to fit exactly into the defect of the bony ear canal wall. This can be done most easily, and without wasting valuable cartilage, by first making a template from a piece of sterile metal foil such as that used in suture material packing. Once the cartilage is shaped, it then needs to be worked so that it adapts to form a curve matching the contour of the normal ear canal wall. This can be achieved by thinning and cross-hatching. The cartilage is then inserted into slots already cut into the superior cavity wall, along the zygomatic root and inferiorly along the facial ridge. The slots are made with a 2-mm diamond burr. The superior slot starts at the junction of the attic wall with the anterior meatal wall, and passes laterally. The inferior slot starts just lateral to the facial nerve, and continues along the facial ridge (Fig. **832**). After ossiculoplasty and closure of the drum perforation with an underlay fascia graft, the previously trimmed septal cartilage is placed into the slots in such a way that it remains concave towards the meatus in the same way as the normal ear canal (Fig. **833**). Sufficient communication between the tympanic cavity and the mastoid cavity — the artificial aditus — must be secured. Smyth lined the space with a thin silastic sheet in order to maintain its patency.

The fascia covers the perforation as well as the meatal surface of the septum. The lateral third of the cartilage can be covered with a small Palva flap, so that a situation similar to that illustrated in Figure **831**, can be achieved, using tragal cartilage.

Of 10 cases operated on, the cartilage was displaced posteriorly into the cavity in two cases when a lateral periosteum–subcutis flap had not been used. A fistula developed through the septum in one case, and this was closed secondarily. In the remainder of the cases, the shape of the new ear canal appeared to have been maintained to a large degree at follow-up 2–2½ years after surgery.

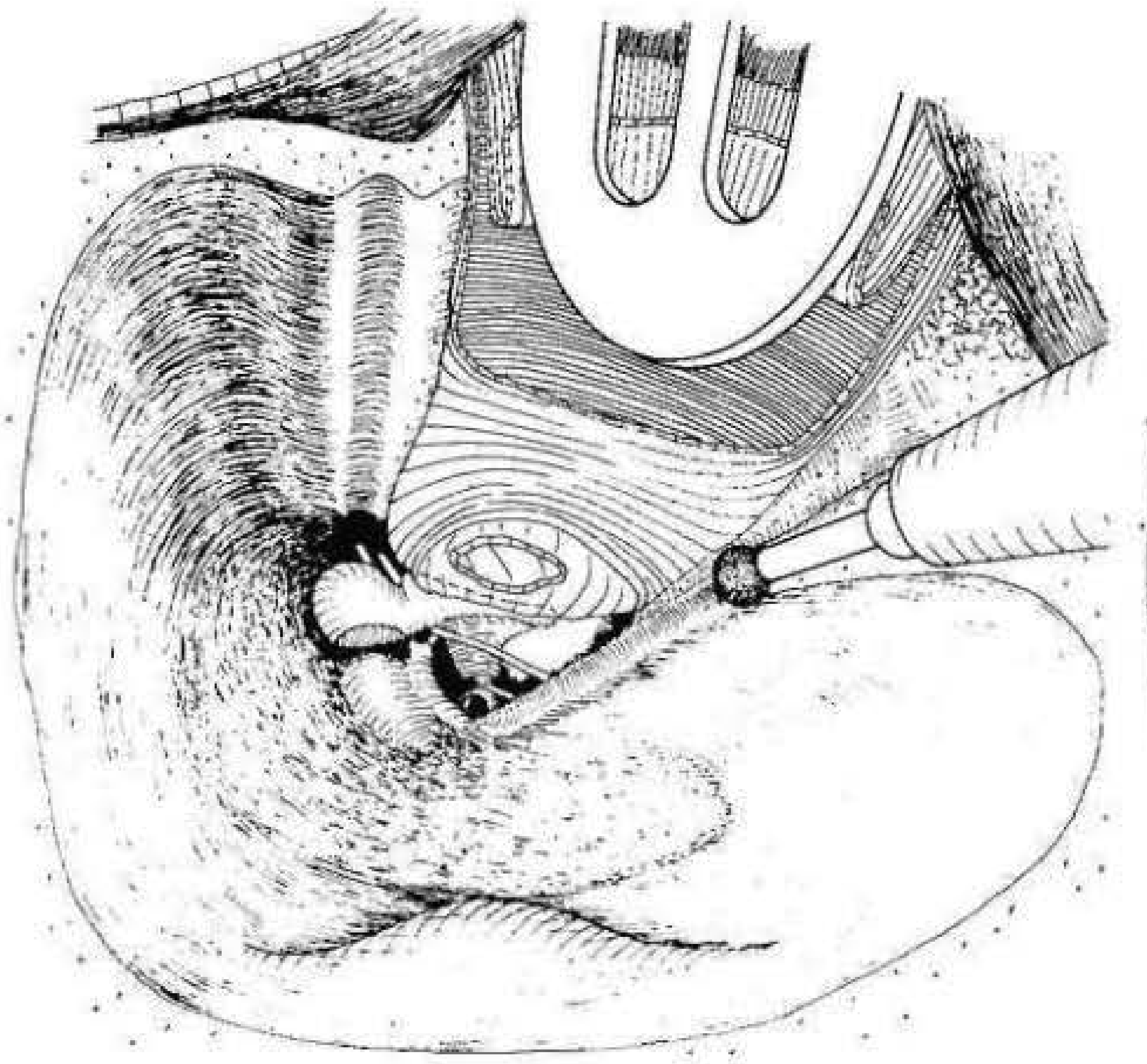


Fig. **832** **Ear canal wall reconstruction with allogenous septal cartilage** (Smyth and Dowe). After a canal wall–down mastoidectomy with removal of the bridge, a posterior perforation and interposition of a piece of cortical bone between the stapes and the malleus is performed. A groove is drilled with a 2-mm burr along the zygomatic root. A similar groove is drilled along the facial ridge

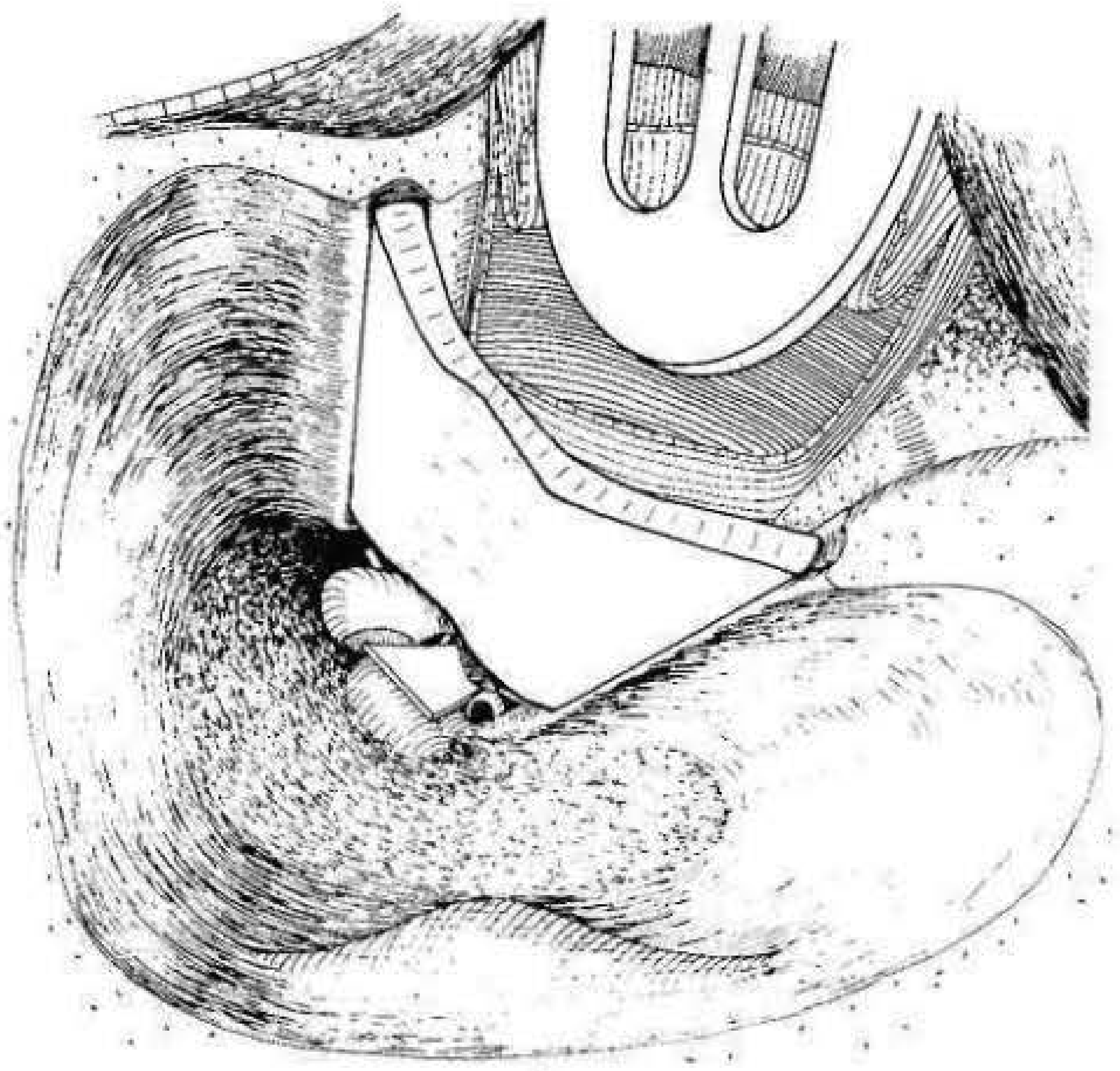


Fig. **833** The septal cartilage is trimmed to the exact size and shape, of the ear canal wall and placed in the grooves. The cartilage will be covered on the meatal side with the fascia. On the mastoid side, a Palva flap will cover the lateral part of the cartilage. A new tympanic isthmus is secured with a piece of thin Silastic

Pappas et al. (1981) used septal cartilage in the reconstruction of the ear canal and in scutumplasty. They advocate incision of the cartilage with several parallel-placed V-notched incisions through two-thirds of its thickness on the convex side, in order to increase its flexibility so that the cartilage will adapt to the curvature of the defect, as illustrated in Chapter 6 (Figs. **360–361**).

Strauss (1974) used exactly the same technique as Smyth and Dowe, with superior and inferior grooves and a large septal cartilage graft, stored in Cialit (otimerate sedium). He performed small incisions on the mastoid aspect of the cartilage in order to achieve convexity. Using a Palva flap on the mastoid aspect of the cartilage and a large piece of fascia on the meatal aspect, the septal cartilage was extruded in only 5% out of 40 operated ears. In two patients, fistulas were found at the junction between the septal cartilage and the skin, and this could be avoided by using a Palva flap behind the septal cartilage.

Information is needed on the late results of ear canal reconstructions using allogenous septal cartilage.

Knee Cartilage

Wehrs (1972, 1978) used allogenous knee cartilage together with allogenous tympanic membrane with the malleus. The advantage of homograft knee cartilage should be its natural, concave shape and thin lower edge. The thin lower edge exactly matches the shape of the bony annulus in previous radical canal wall–down operations. Wehrs cuts grooves along the superior cavity wall and along the facial ridge, similar to the method illustrated previously for septal cartilage (Fig. **832**). Additionally, he shapes the knee cartilage in a special way, creating a thin strip of cartilage to overlap the meatal sides of the facial ridge and the zygomatic root (Fig. **834**). Using a thin foil template, the defect in the posterior ear canal wall is evaluated as to size and shape. The template is then trimmed so that it overlaps the facial ridge and dural plate, but does not block the mastoid antrum. Using this template, a block is cut from a selected specimen, and this block is then grooved at each end, so that a thin sheet of the cartilage will overlap the meatal plate and the facial ridge, to prevent formation of retraction, while the thicker poste-

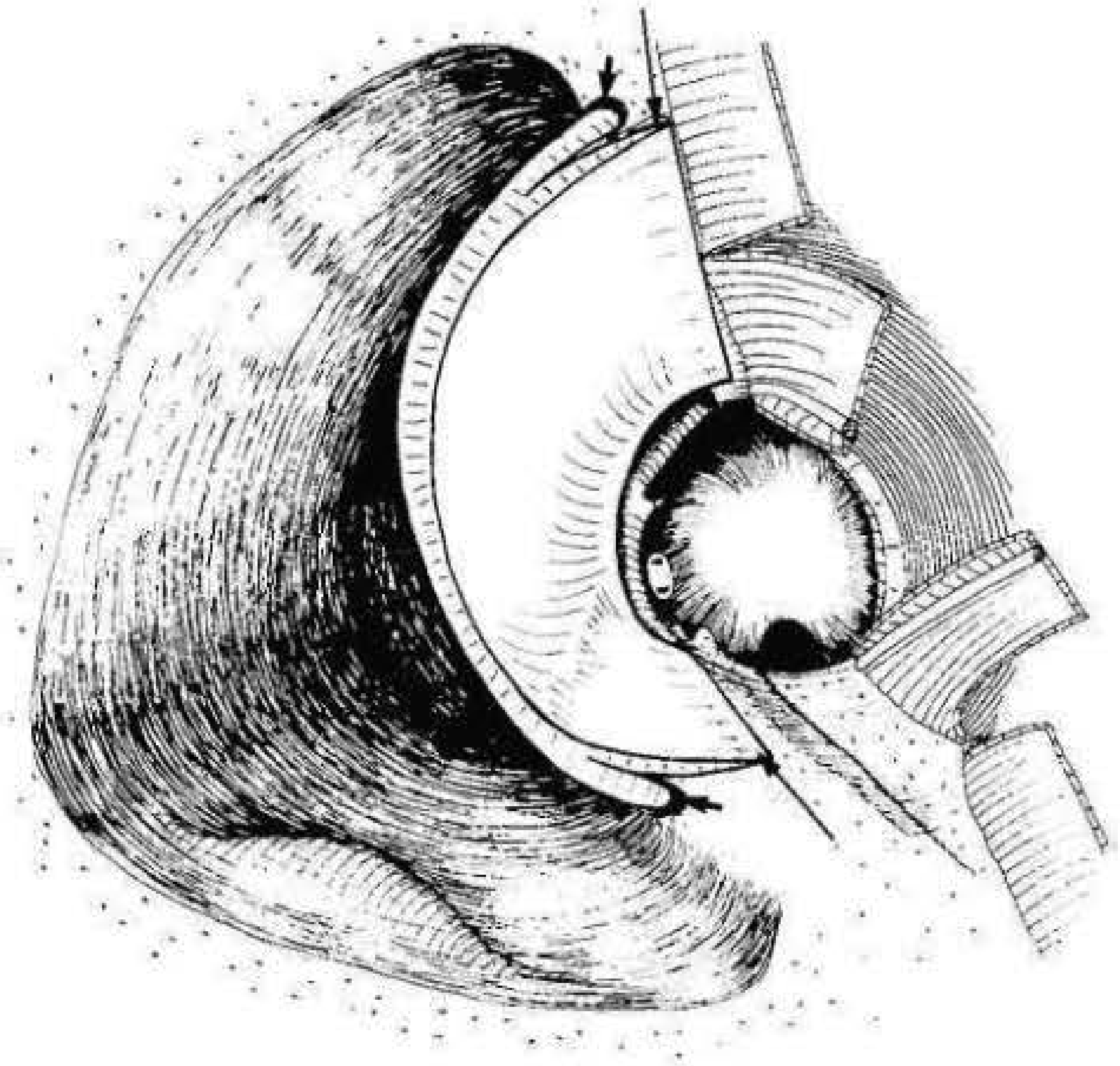


Fig. **834** **Ear canal wall reconstruction with allogenous knee cartilage and allogenous drum** (Wehrs) In a case with total perforation and no ossicles, grooves are created along the superior wall of the cavity and along the facial ridge (short arrows). The knee cartilage is trimmed in such a way that the thin slice covers the meatal side of the ear canal wall anteriorly, and the facial ridge inferiorly (long arrows). The thicker part of the cartilage fits into the grooves. Ear canal skin flaps are elaborated

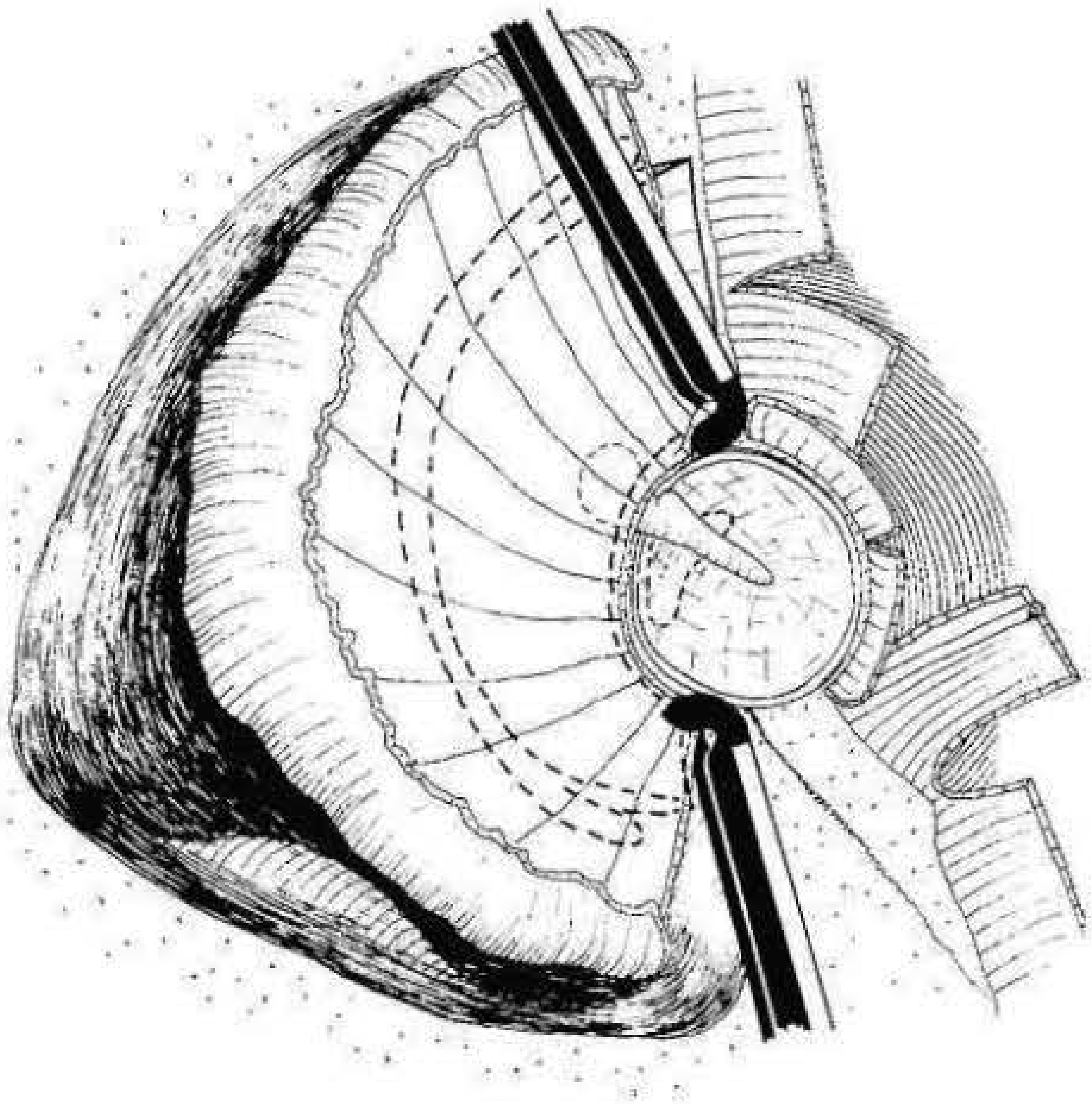


Fig. **835** A homograft drum, with no attached skin but with an attached malleus handle, is placed on the patient's denuded annulus, and an L-shaped columella is placed between the footplate and the new malleus handle. Using two forceps, a large piece of fascia is pulled medially along the ear canal wall to cover the allogenous drum and the entire knee cartilage ear canal. Finally, the epithelial flaps are replaced

rior sheet is supported by the bony grooves (Fig. **834**). The tympanic cavity is then reconstructed with allogenous tympanic membrane and attached malleus, and the ossiculoplasty is performed. The drum is placed on the annulus, and fascia is used to cover the entire allogenous drum and the septal cartilage (Fig. **835**).

In 63 patients with a follow-up of at least one year, Wehrs (1978) found satisfactory anatomical results in 57% of cases (36 ears). "Satisfactory" results referred to normal contours of the ear canal and tympanic membrane, no crusts in the retraction pockets, no areas of discharge, and no restriction on swimming and showering. Twenty-seven patients had recurrent perforation or retraction pockets with crusts and recurrent discharge, and nine underwent repeat surgery due to retraction of the cartilage wall. In four reoperated cases, there was perforation of the new tympanic membrane and recurrent cholesteatoma in a further two cases.

Late results with this method have not been published.

Reconstruction with Autogenous Bone

Autogenous bone used in ear canal reconstruction with ventilation of the cavity includes mastoid cortical bone, iliac crest bone, and autogenous bone paste.

Mastoid Cortical Bone

Mastoid cortical bone has been used by Portmann (1966), Ekvall (1973), Pou (1977), Magnan et al. (1991), and others. The problem in ear canal wall reconstruction with mastoid cortical bone is the need to harvest sufficiently large pieces of the cortical bone to be shaped as an ear canal and placed into two grooves in the cavity walls. This can be impossible in cases with previous mastoidectomy and previous radical operations. The other problem is the shaping of the bone, which is technically difficult and time-consuming. During shaping, the edges of the cortical bone can fracture, and the new ear canal can become too small.

Using a retroauricular approach, Ekvall (1973) elevates a large musculoperiostal flap, based both

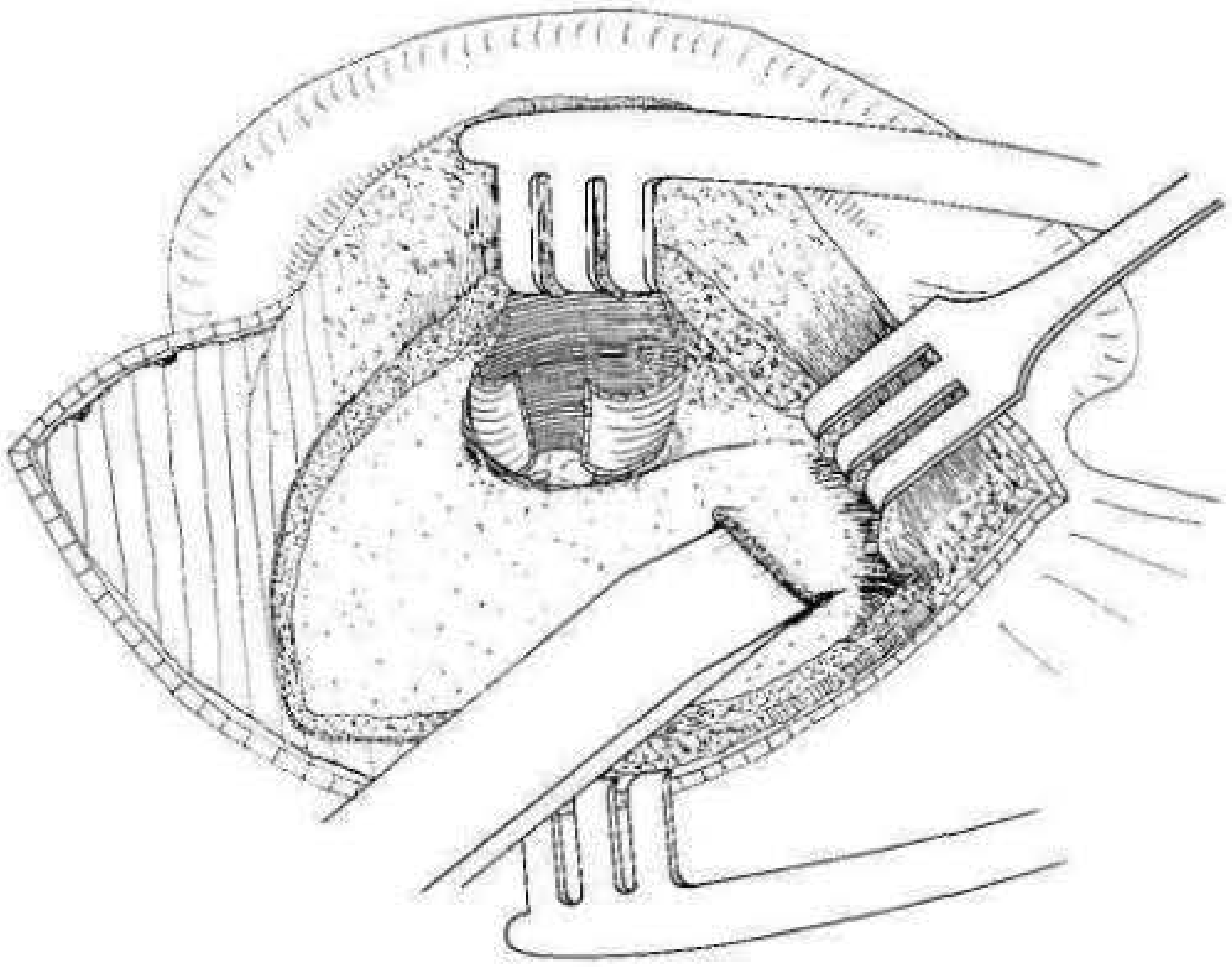


Fig. **836** **Ear canal wall reconstruction with mastoid cortical bone** (Ekvall). After a retroauricular incision far posterior to the postauricular fold, an incision through the subcutis and periosteum is performed, and a large, double-based flap is elevated, consisting superiorly of part of the temporalis muscle, posteriorly of the periosteum subcutaneous tissue and postauricular muscle, and inferiorly of the fibers of the splenius capitis and sternocleidomastoid muscles. A large piece of cortical bone is harvested from the tip of the mastoid process using a large, thin chisel. The lateral, inferior, and superior ear canal skin flaps are elevated

superiorly and inferiorly, and consisting of part of the temporalis muscle, fibrous tissue, and periosteum from the mastoid process. This double-based flap is elevated and held in place anteriorly with a selfretaining retractor. Then a large piece of bone is harvested using a thin, straight, broad chisel (Fig. **836**). After elevation of large inferiorly and large superiorly pedicled ear canal skin flaps, a canal wall–down mastoidectomy is performed. After ossiculoplasty, grooves are drilled along the superior border of the cavity and along the facial ridge. The cortical bone is shaped and placed as the new ear canal wall into the grooves (Figs. **837, 838**). The musculoperiostal flap is placed over the lateral part of the new bony ear canal, and forms the lateral part of the ear canal itself. Finally, the perforation and the new ear canal wall are covered with fascia or perichondrium, and the epithelial flaps are replaced (Fig. **839**). Ventilation through the isthmus is maintained by a large piece of Silastic, extending from the tympanic cavity through the isthmus to the mastoid cavity. Ekvall (1980) has abandoned this method, and prefers firm obliteration of the cavity. His reason for changing the method was the frequency of retraction around the medial edge of the newly formed ear canal wall and the lack of ventilation of the mastoid cavity, despite extensive use of Silastic sheeting. Magnan et al. (1991) prefer an ear canal made of mastoid cortical bone rather than car-

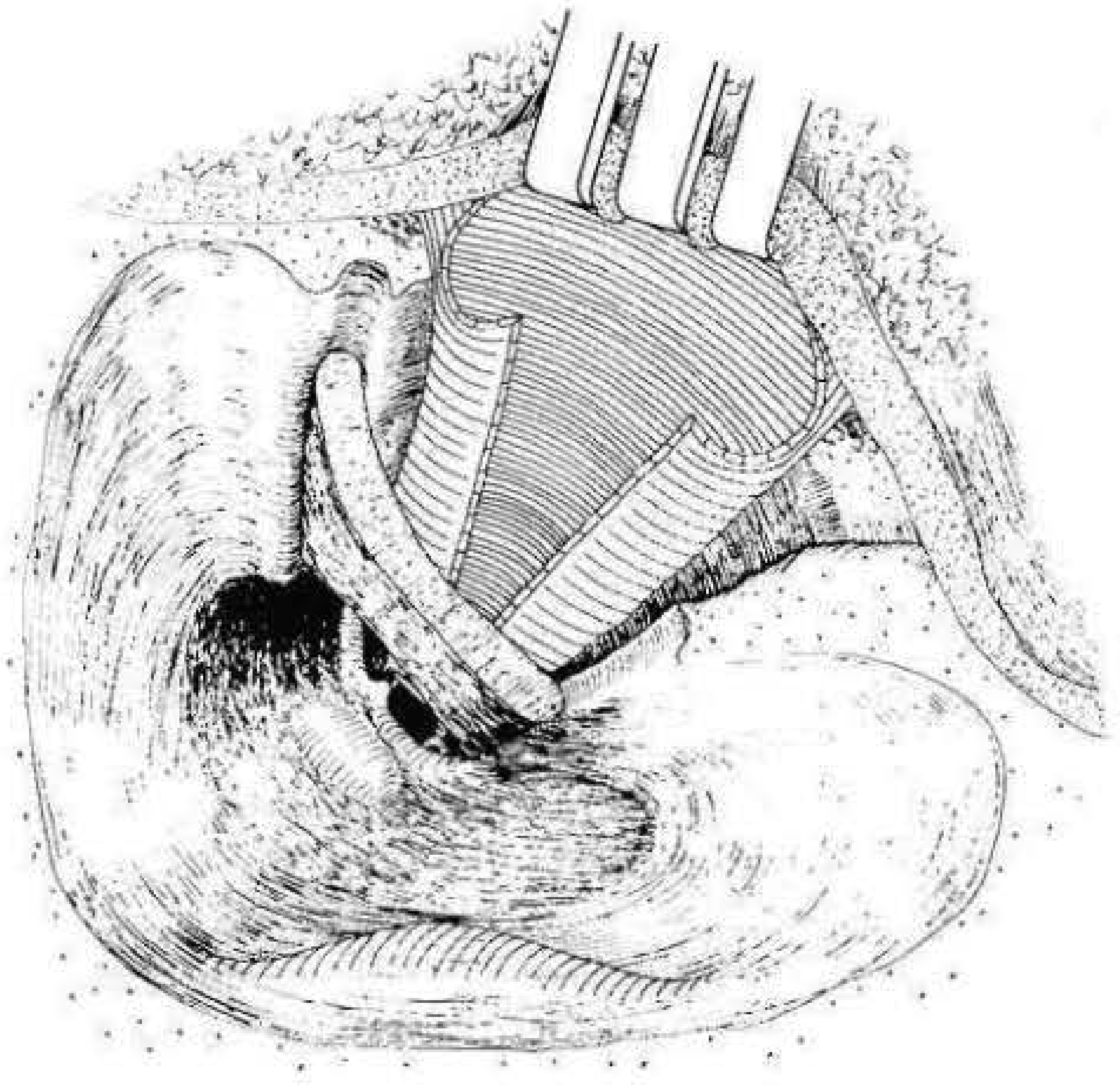


Fig. **837** After drilling of superior and inferior grooves, the shaped and prepared piece of cortical bone is placed in the grooves, allowing a wide tympanic isthmus

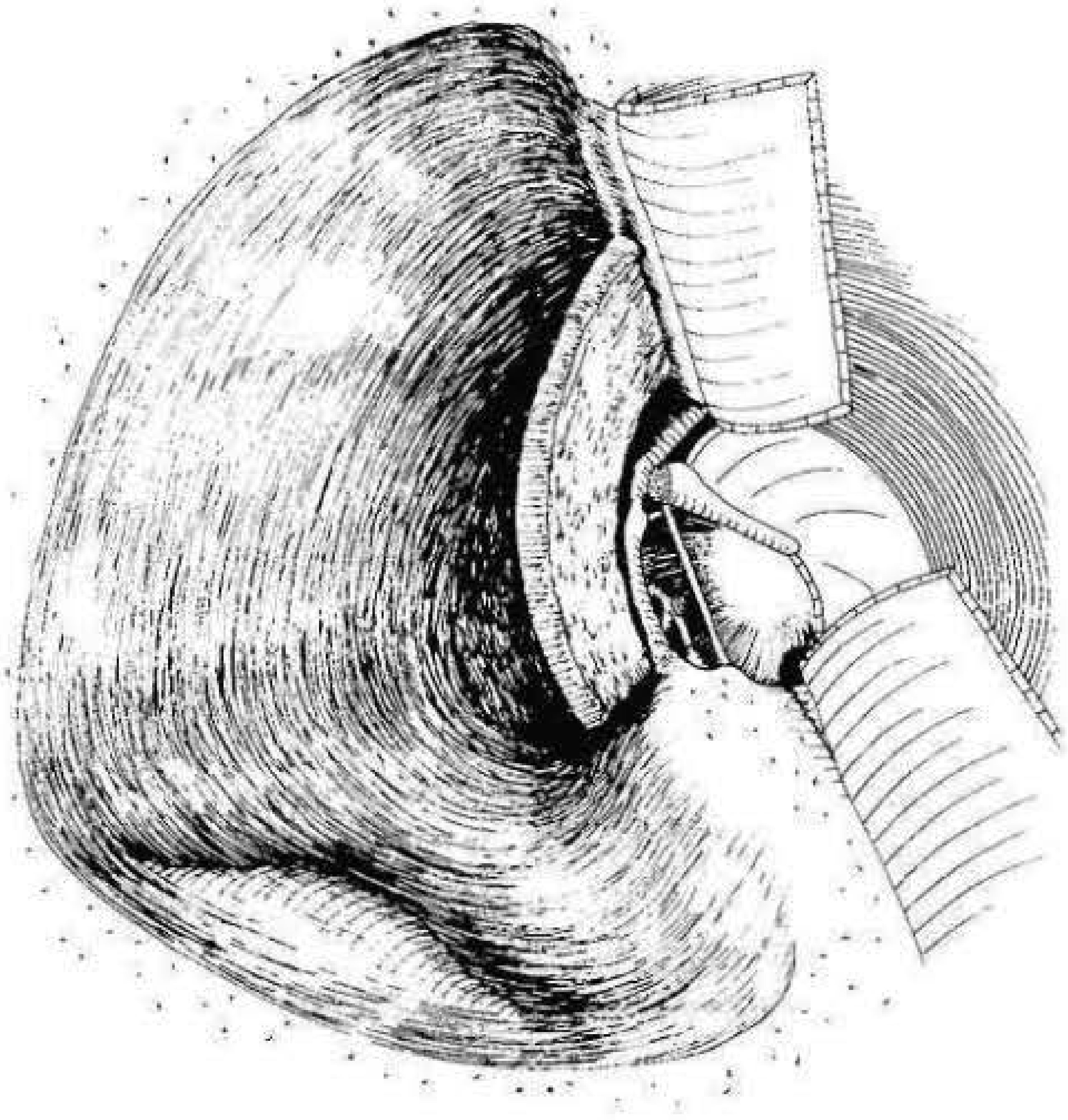


Fig. **838** The new ear canal wall is in position, illustrating an absent lateral reconstruction with bone tilage in the reconstruction of old radical cavities. This ensures good viability for the covering skin, but late results are again lacking.

Iliac Crest Bone

The use of autogenous iliac crest bone was introduced by Schiller in 1961, mainly to obliterate the mastoid cavity, but the iliac crest has also been used in ear canal reconstruction in order to ventilate the cavity. The bone harvested from the iliac crest is large enough to be shaped to the proper size of the bony ear canal, even in cases with a very low facial ridge (see Chapter 20).

Bone Paté

Autogenous bone paste, allogenous lyophilized dura, and allogenous tympanic membrane with a malleus–incus block are used in a sophisticated method, described by Perkins (1976) of reconstructing the ear canal with bone paté, placed in a retainer made of allogenous dura. The technique is as follows: *Endaurally,* an anteroinferiorly-based ear canal skin flap is created by incising the canal skin close to the annuius, going over the facial ridge, and then back through the inferior part of the cavity laterally toward the 6-o'clock position. Similarly, an anterosuperiorly based skin flap is created by continuing the incision along the annuius, laterally towards the mastoid legmen, and then further laterally toward the 12-o'clock position (Fig. **840**). Before a retroauricular incision is performed, a 3×4-cm piece of fascia is obtained from the lateral surface of the temporalis muscle through a *separate incision* superior to the pinna (Vol. 1, Fig. **230**). After a *retroauricular incision,* a large amount of bone paste is collected using a special facility described by Perkins (Fig. **841**). The bone paste is passed through a piece of fine rayon, supported by a stainless steel mesh strainer. Excess fluid is gently squeezed from the paste by twisting the rayon. After the cavity has been entered, the superior and inferior ear canal skin flaps are elevated (Fig. **842**), the tympanic cavity is cleaned, the annuius is removed, and the tympanic cavity is prepared for the allograft drum–

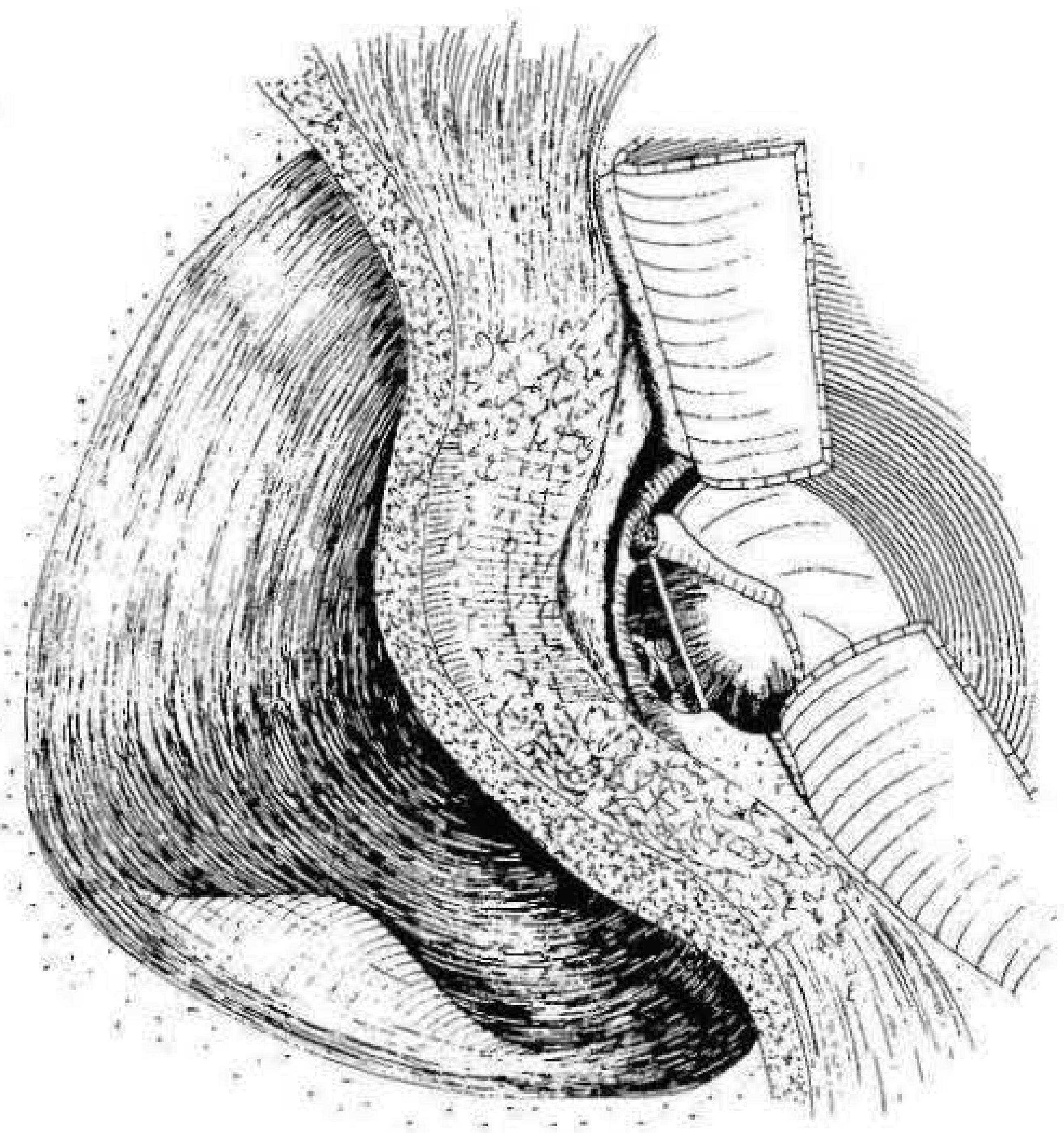


Fig. **839** The lateral part of the reconstructed ear canal is covered with the muscoloperiostal flap, attached superiorly and inferiorly. The medial part, as well as the drum perforation, will be covered with a large piece of fascia as underlay graft, and the skin flaps will be replaced

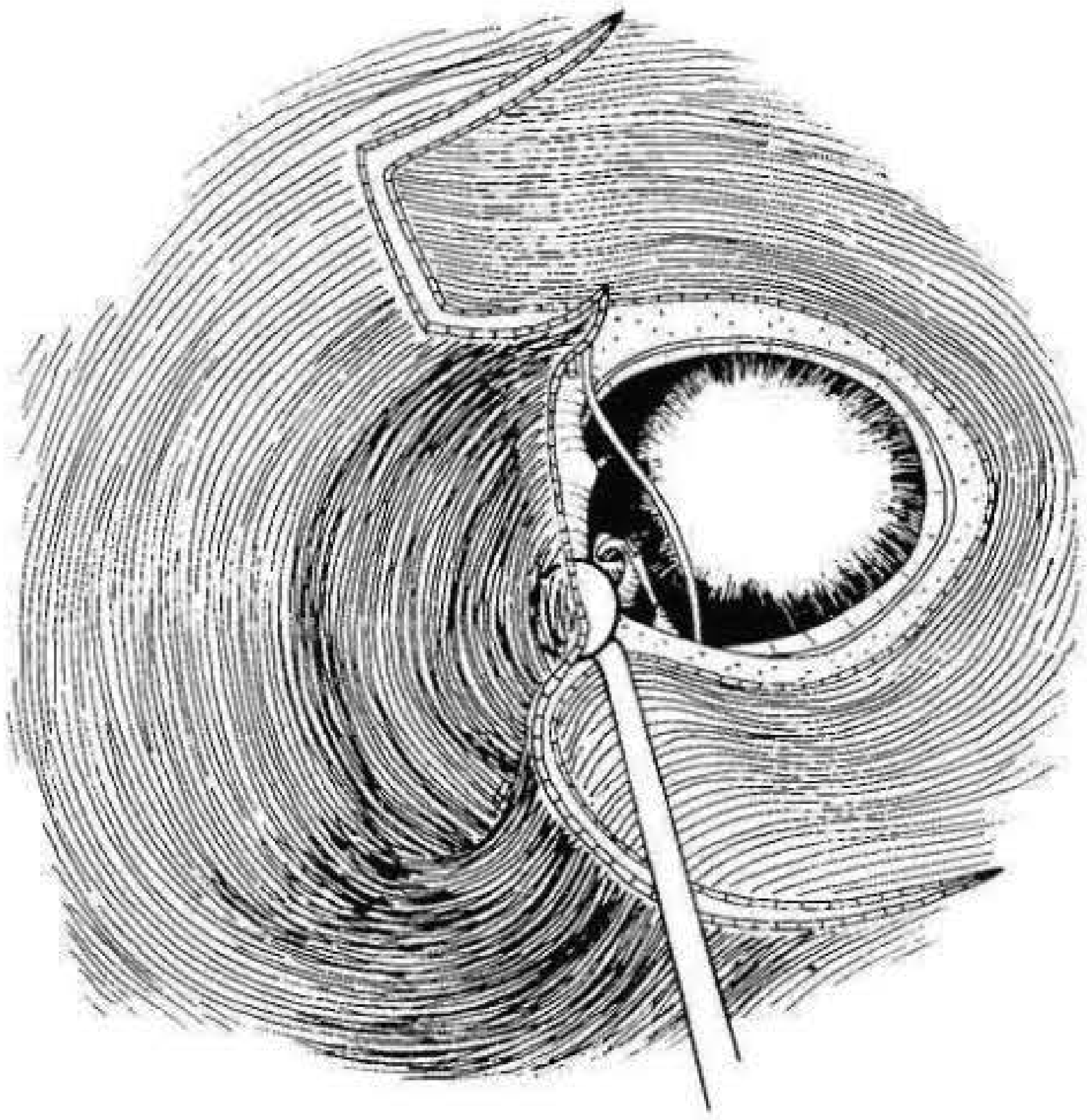


Fig. **840** **Ear canal reconstruction with autogenous bone paté and allogenous dura** (Perkins). An incision is performed close to the fibrous annuius, starting at the 6-o'clock position and continuing posteriorly over the facial ridge, continuing along the inferior part of the cavity, and then moving laterally toward the 6-o'clock position. A large, anteroinferiorly-based flap is thus created. Superiorly, a similar incision runs along the anterior annuius laterally toward the mastoid tegmen, and then further laterally toward the 12-o'clock position, creating a large, anterosuperiorly-based flap. In the tympanic cavity, there is no drum and no malleus; only the stapes is present. The drum remnant with the fibrous annuius will be removed

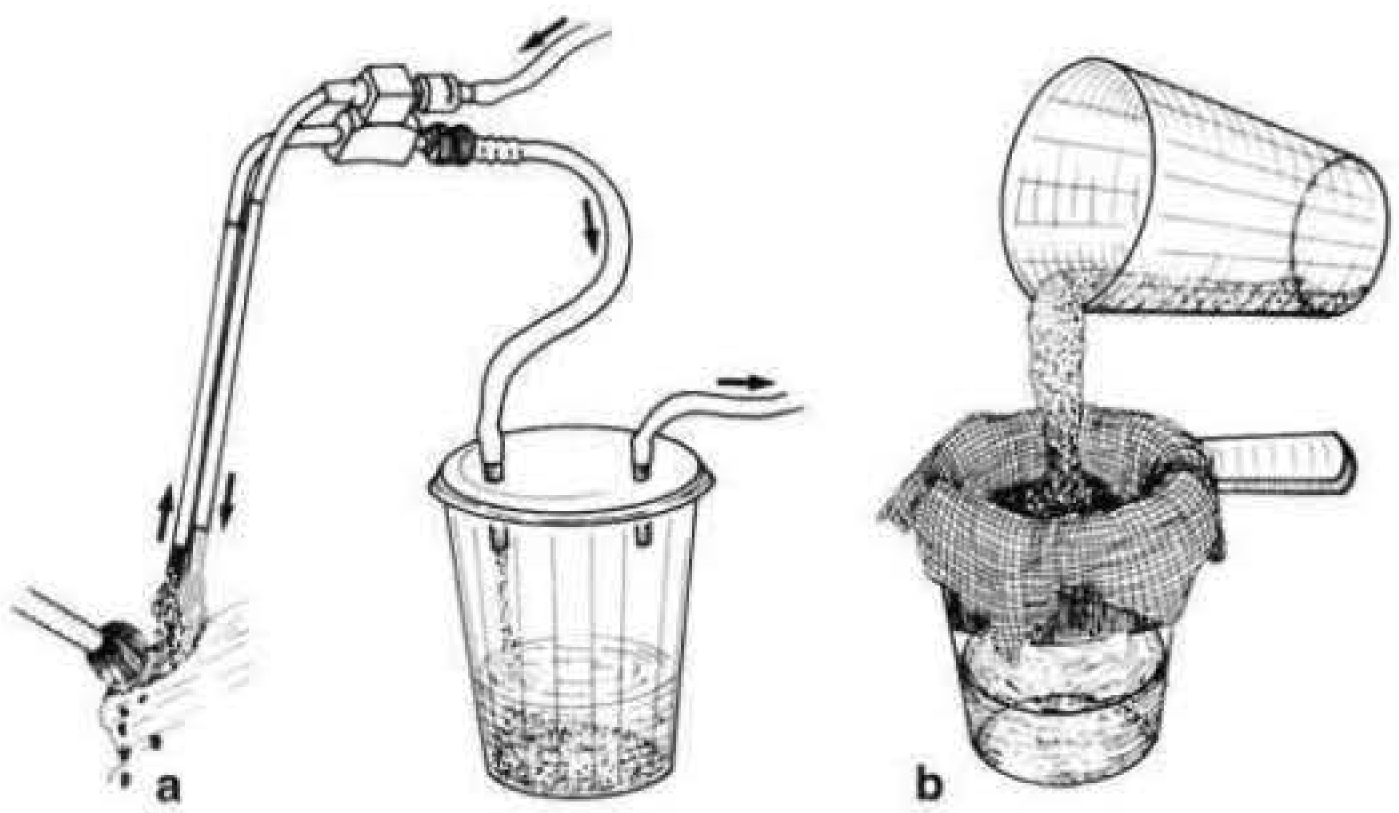


Fig. **841** **Harvesting of bone paté** (Perkins), **a** The bone paté is suctioned into a collector (arrows), using a suction irrigation device during drilling. **b** The contents of the suction trap bottle are filtered through a fine rayon mesh, leaving the bone paté on its surface

ossicle block, which is placed in the tympanic cavity. The allogenous drum is attached with its fibrous cuff placed on the denuded bone around the tympanic cavity area. The dried temporalis fascia is then shaped to fit the curve of the anticipated posterior ear canal wall, and placed so that it lies adjacent to, but not overlying, the pars tensa of the allograft tympanic membrane. This fascia lies anterior to the long posterior cuff of the allograft (Fig. **843**).

When the allograft drum–ossicle bloc is being placed, attention should be given to attaching the lenticular process to the patient's stapes or — if the stapes is absent — to the footplate area, linking the allogenous long process of the incus to footplate with a columella.

Behind the fascia, a large piece of allogenous dura is preshaped to the curve of the posterior canal wall and placed so that it serves as a retainer for the bone paste. Several adjustments have to be made until the piece fits anteriorly at the mastoid tegmen and inferiorly at the facial ridge. Using a small elevator, the bone paté is introduced into the dural mold (Fig. **844**). Perkins mixed the paté with a small amount of the patient's own blood, but today allo-

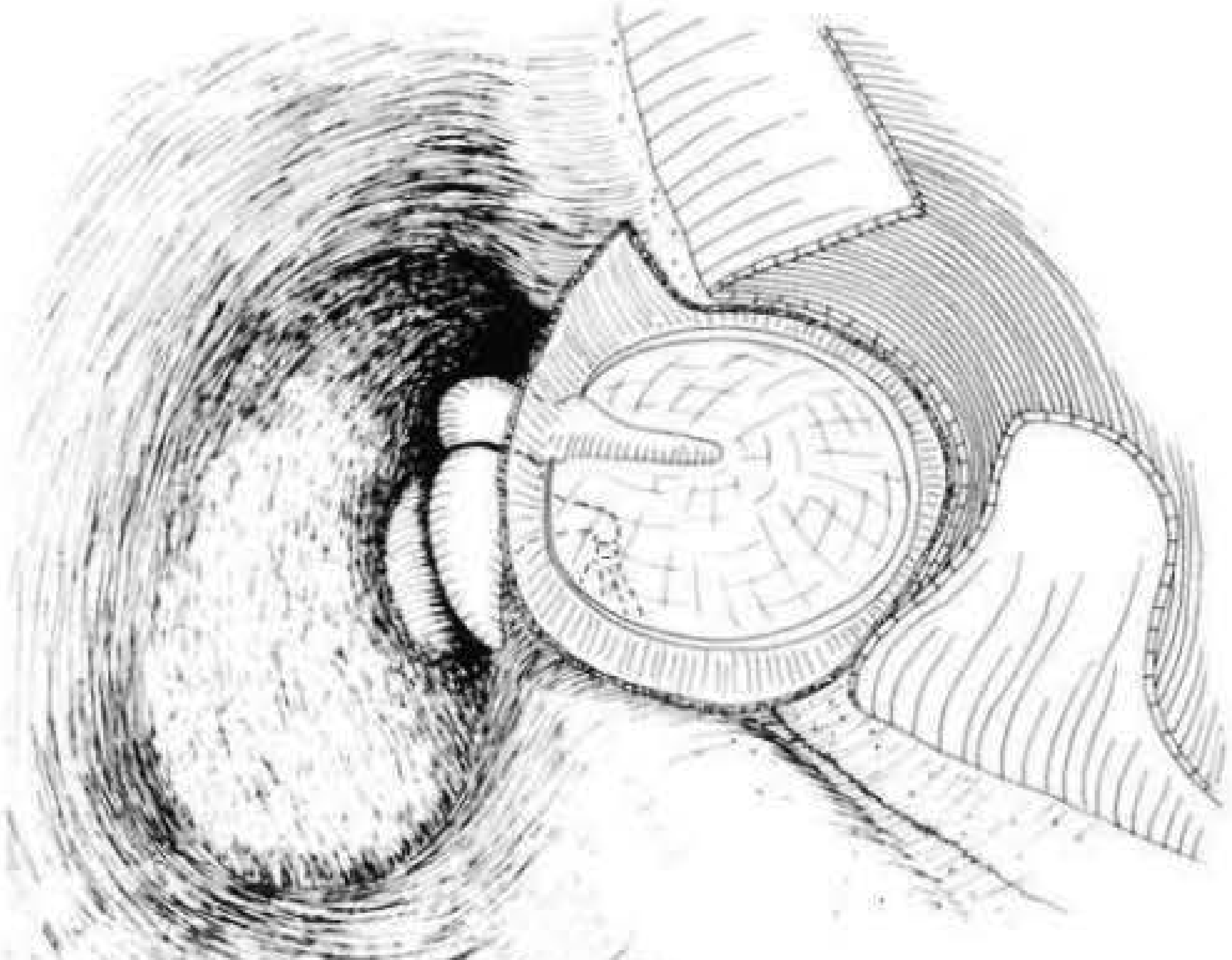


Fig. **842** **Placement of allogenous drum–malleus–incus block.** After a retroauricular incision, the anterosuperior and anteroinferior flaps are elevated. The tympanic cavity is reconstructed with an allogenous drum–malleus–incus block. The incus is carefully placed on the capitulum of the stapes. The fibrous annulus is adapted to the sulcus of the bony annulus. A fibrous cuff, consisting of the allogenous ear canal skin without epithelium, is attached to the annulus of the drum. This cuff is carefully adapted onto the denuded bone of the ear canal all the way round, and will be placed on the new ear canal wall posteriorly

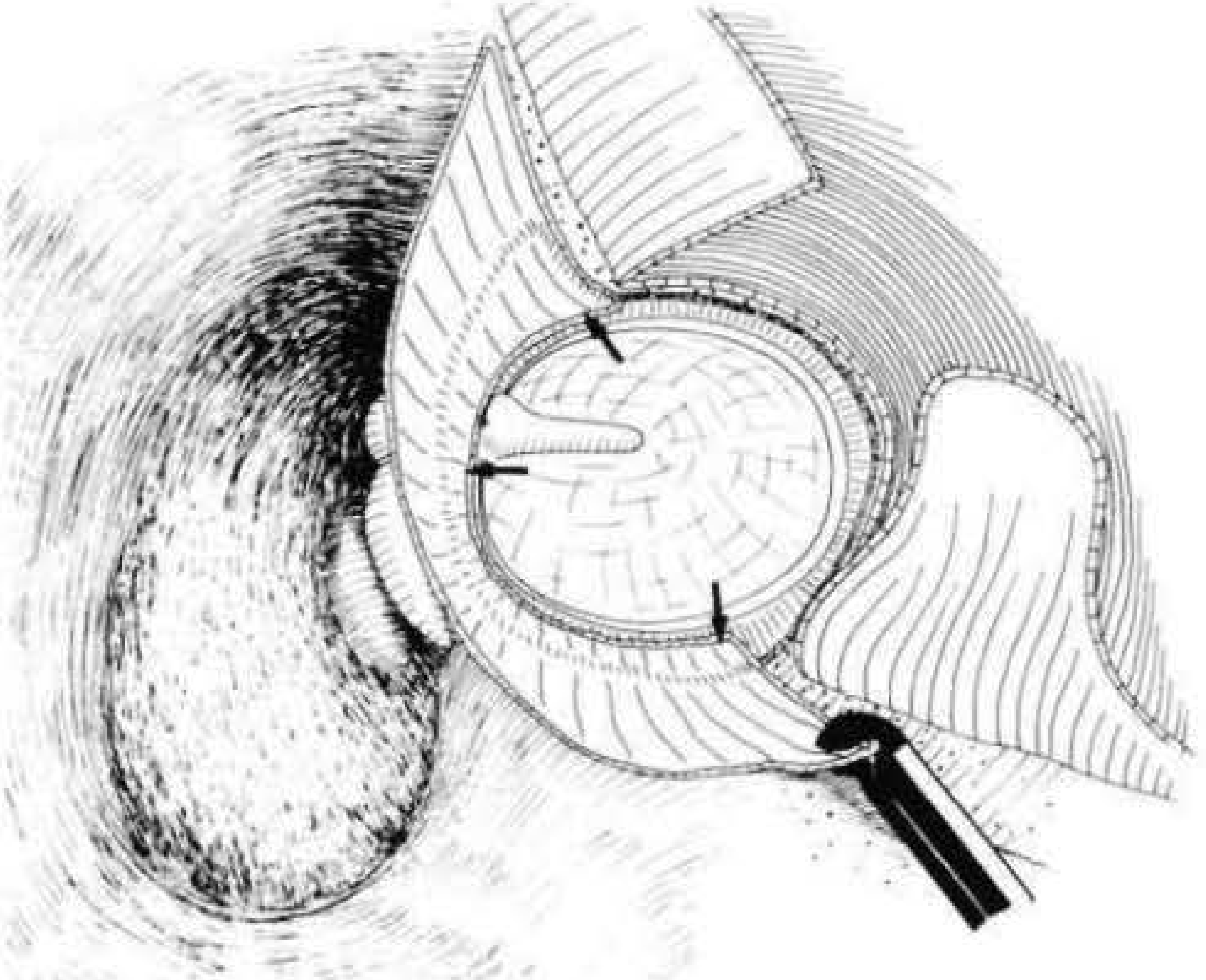


Fig. **843** A large piece of fascia is placed on the cavity walls superiorly and inferiorly. Medially, it is placed close to the pars tensa of the allogenous drum, covering the large fibrous cuff posteriorly (arrows)

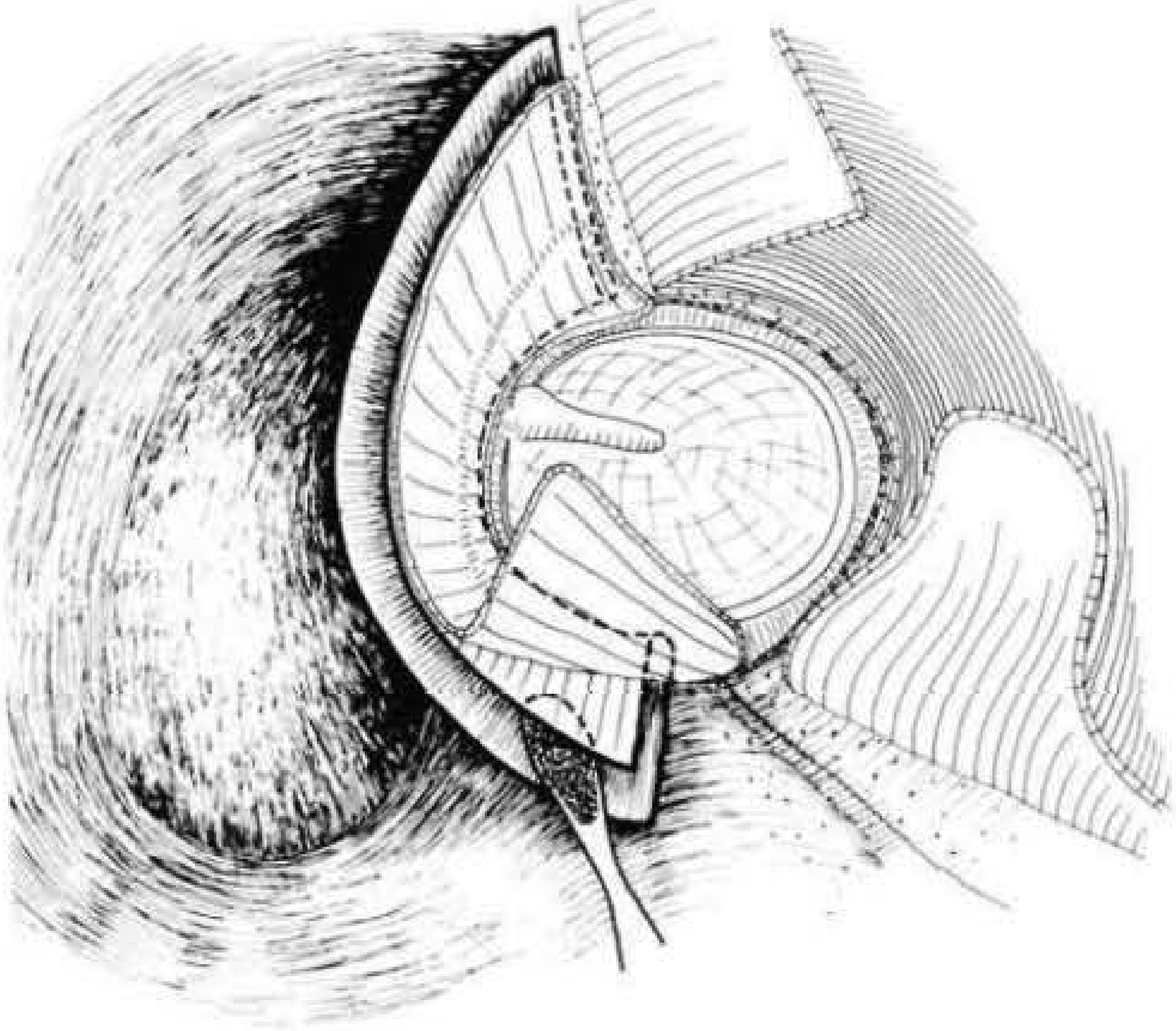


Fig. **844** A large piece of allogenous dura is cut, preshaped into the curve of the posterior canal wall, and placed behind the fascia and the fibrous cuff as a retainer for the bone paté, which will gradually be placed in the retainer using a small rugine

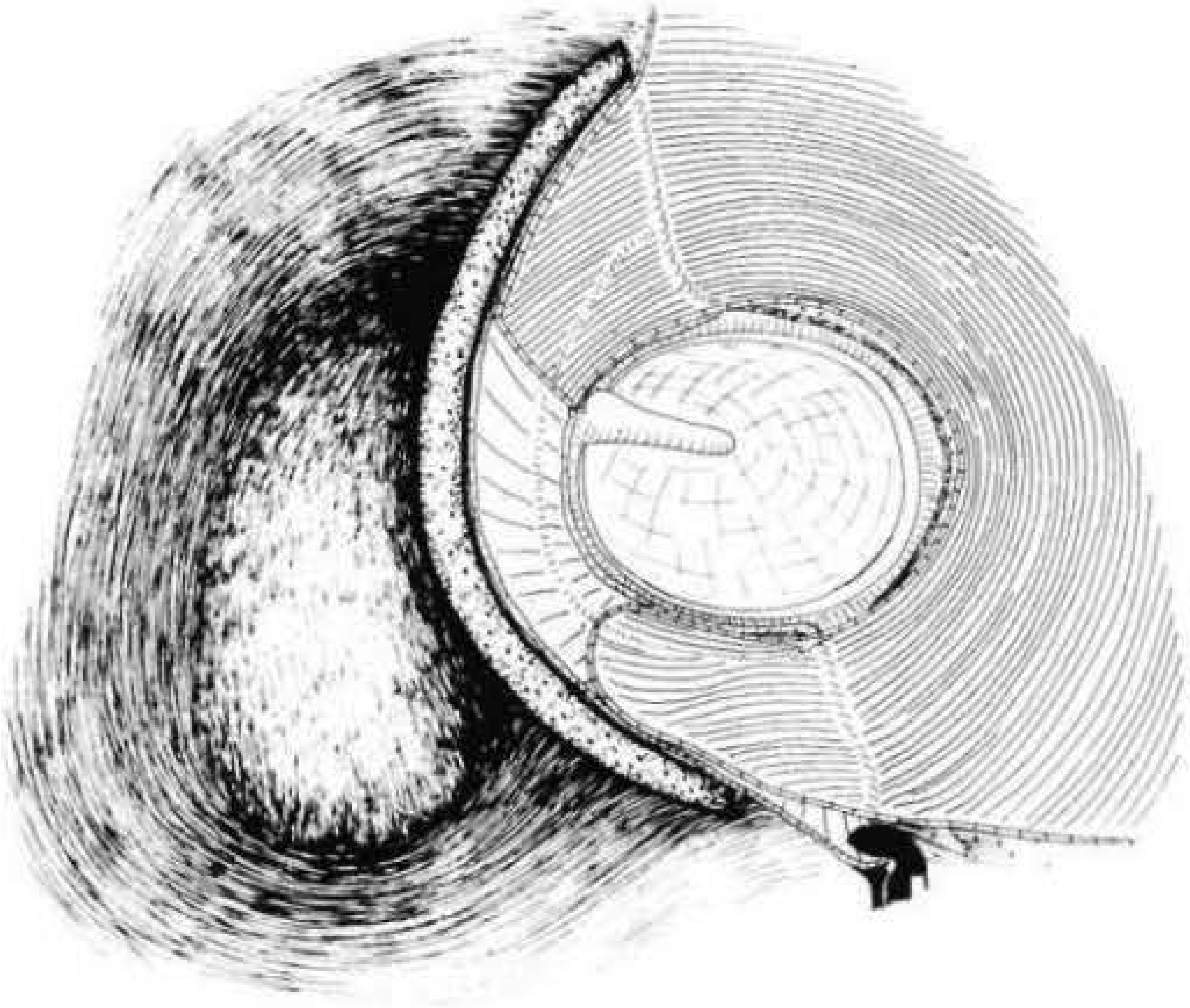


Fig. **845** The entire cuff is filled with bone paté and covered with fibrin glue. The ear canal skin flaps are replaced, and the fascia is further adapted under the skin flaps

genous fibrin glue is used instead of blood. After the dural mold has been filled with bone paste, the superior and inferior skin flaps are replaced (Figs. **845**, **846**). The postauricular incision is sutured, and the ear canal is packed with Gelfoam, soaked with chloramphenicol, and then gauze (Figs. **845**, **846**).

Twenty-five cases were evaluated with respect to the reconstruction of the ear canal wall. The wall was completely intact in 80% of cases, while minor defects were present in 12% and major defects in 8%. The reconstructed ear canal wall was hard, and had all the characteristics of normal bone. Long-term follow-up of the earliest patients indicates that once the wall is mature and firm, there is no evidence of resorption over five years. However, systematic late results are needed. Re-perforation of the allograft drum was reported in 18%, and in 12 cases a second-stage procedure was performed. This re-perforation rate is unacceptably high. This very sophisticated, but interesting, ear canal reconstruction method can be "modernized" using fascia lata instead of allogenous dura, and perichondrium or fascia instead of allogenous drum. Also, laterally an anteriorly-based Palva flap provides better support for the ear canal.

Bone paté is used for reconstruction of the scutum, and is currently widely used in various obliteration methods.

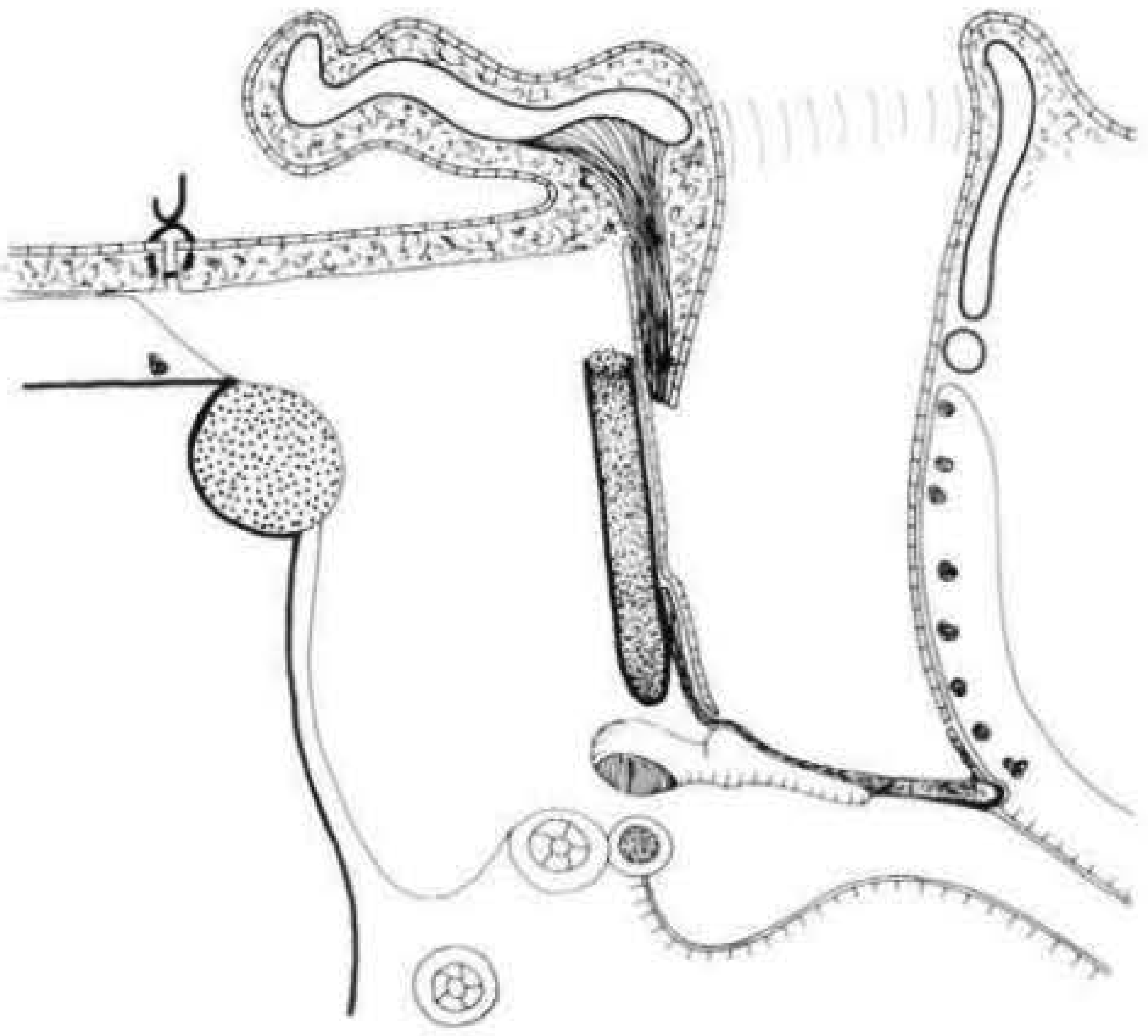


Fig. **846** Side view of Perkins's method of reconstructing the ear canal using bone paté. The fibrous cuff of the allogenous drum is attached to the bone of the superior cavity wall and the facial ridge. The allogenous dura cuff is filled with bone paté. On the meatal side, fascia covers the allogenous dura

Allogenous Ear Canal Wall Transplantation

In the mid-1970s, transplantation of an entire allogenous posterior ear canal wall, together with the drum and attached malleus was performed (Betow 1975, Smith 1975) in cases with a previous radical operation that had resulted in an extremely large mastoid cavity and high facial ridge. The allogenous ear canal wall is harvested with the attached tympanic membrane and malleus, and a generous periosteal cuff. The advantage of this type of graft is that the relationship of the scutum to the tympanic membrane is anatomically correct, and the shape of the allogenous posterior canal wall is perfect. After a postauricular incision, a large temporalis fascia graft is harvested, and an anteriorly-pedicled Palva flap is prepared. After removal of the mastoid cavity lining the ear canal, skin flaps are elevated over the facial ridge and over the mastoid tegmen, creating large superior and inferior ear canal skin flaps, similar to the flaps created by Perkins (Fig. **840**). The mastoid cavity is revised, all residual disease is removed, and the drum remnant together with the residual fibrous annulus is removed. The canal skin adjacent to the drum is elevated and preserved to eventually cover the allogenous drum (Fig. **847**). The allograft annulus is positioned in the bony sulcus, the periosteal cuff is approximated to the ear canal, and the anterior tympanomeatal angle is created by placing the periosteal cuff carefully on the bony ear canal wall. The precisely trimmed allograft ear canal wall is placed in position, touching the smoothed wall of the cavity superiorly and the facial ridge inferiorly. The periosteal cuff covers the junction between the facial ridge and the allograft ear canal wall (Fig. **847**). A large piece of fascia is placed over the allogenous ear drum, and also covers the allogenous ear canal (Fig. **848**). The Palva flap is placed behind the allogenous ear canal wall. The ear canal skin flaps are replaced, and the canal is packed with Gelfoam and gauze.

In some cases, the cavity was obliterated behind the reconstructed ear canal wall by placing a larger Palva flap that lined the cavity walls. Smith (1975) used these techniques in 16 consecutive patients, 12 of whom developed an air-containing middle ear space. The long-term stability of the reconstructed allogenous ear canal wall has not been described. Plester (1970) and Portmann (1979) have also used allogenous ear canal wall and allogenous drum, but both soon abandoned the method.

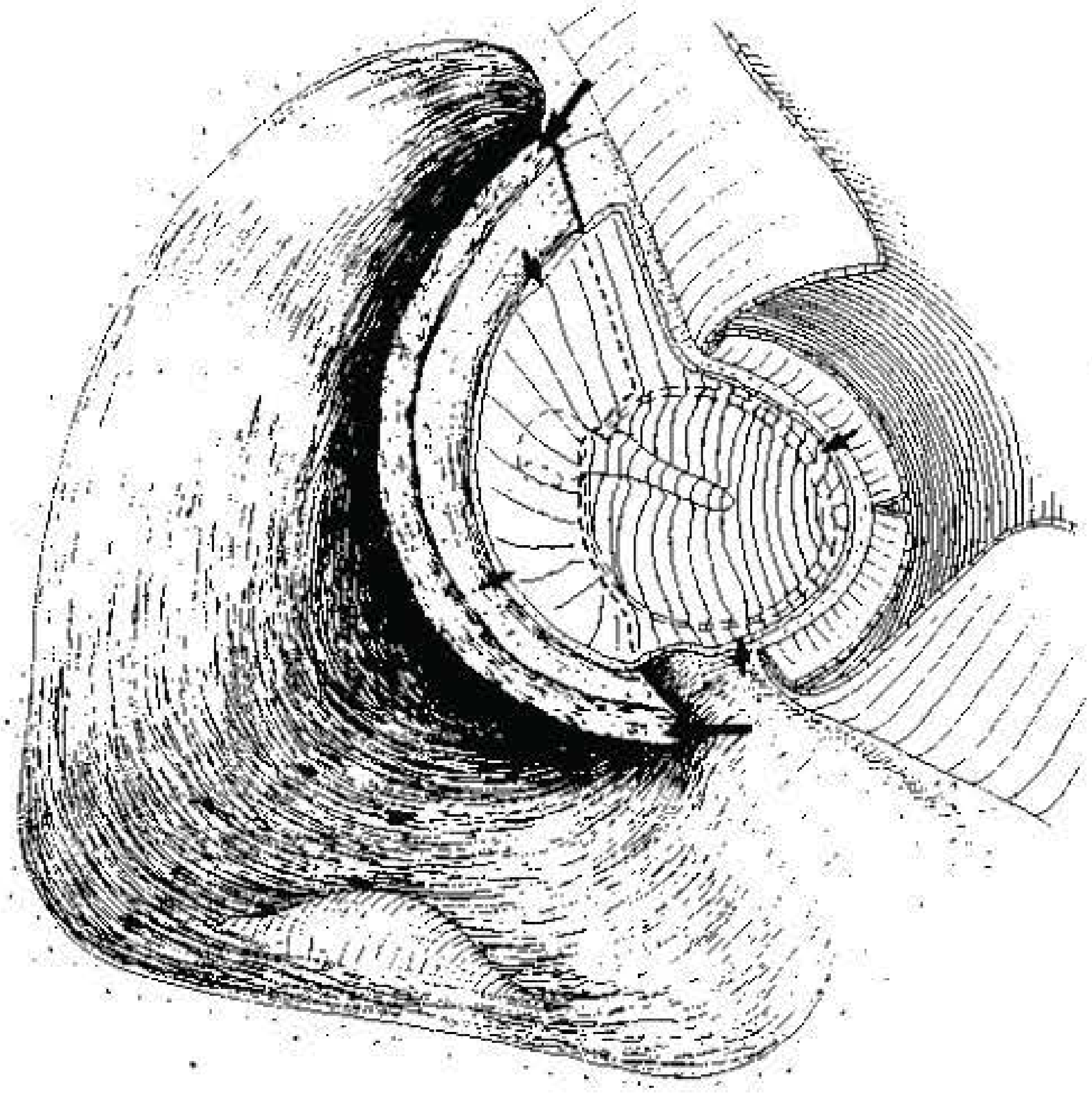


Fig. **847** **Implantation of allogenous ear canal wall together with the allogenous drum.** Superior and inferior ear canal skin flaps are elevated. The ear canal skin is elevated along the fibrous annulus. After removal of any residual tympanic membrane and fibrous annulus, the allogenous drum and the ear canal wail are implanted (large arrows). The allogenous ear canal wall and allogenous drum are covered with fascia (small arrows)

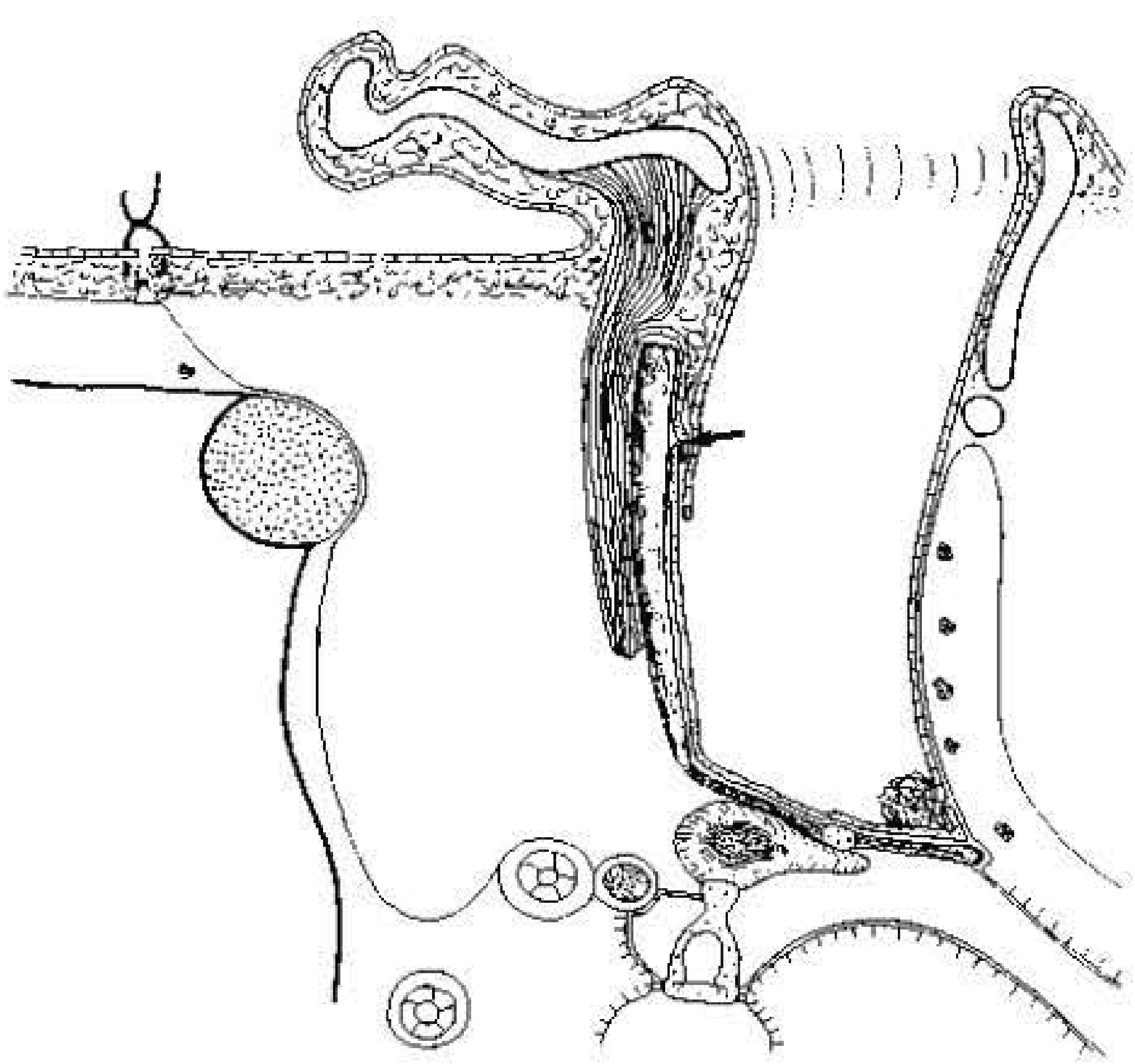


Fig. **848** Side view of the allogenous ear canal implantation. The meatal side of the implanted ear canal wall is covered with a large piece of fascia, which also covers the allogenous drum. The mastoid side is covered with a Palva flap. If necessary, two pieces of fascia can be used (arrow)

Reconstructions with Biocompatible Materials

All allogenous materials have to be covered on the meatal side by an autogenous graft, such as fascia, perichondrium, periosteal flap, canal skin, or Palva flap. The same is the case in reconstructions using biocompatible materials.

Proplast

Shea and Homsy (1974) were the first to introduce this porous plastic into middle ear surgery, particularly in ossiculoplasty (Vol. 1, Figs. **808, 809, 1037**). The important property of Proplast is its porus structure, which allows living tissue to infiltrate it, leading to effective integration and biocompatibility. However, porous plastic prostheses tended to extrude even when covered with cartilage. In reconstruction of the posterior ear canal, a large piece of proplast is shaped to the contour of the natural ear canal and placed in the same way as in reconstruction with an allogenous ear canal (Fig. **847**). However, because of granulation formation on the meatal side and lack of epithelialization, this method has not been used by other surgeons.

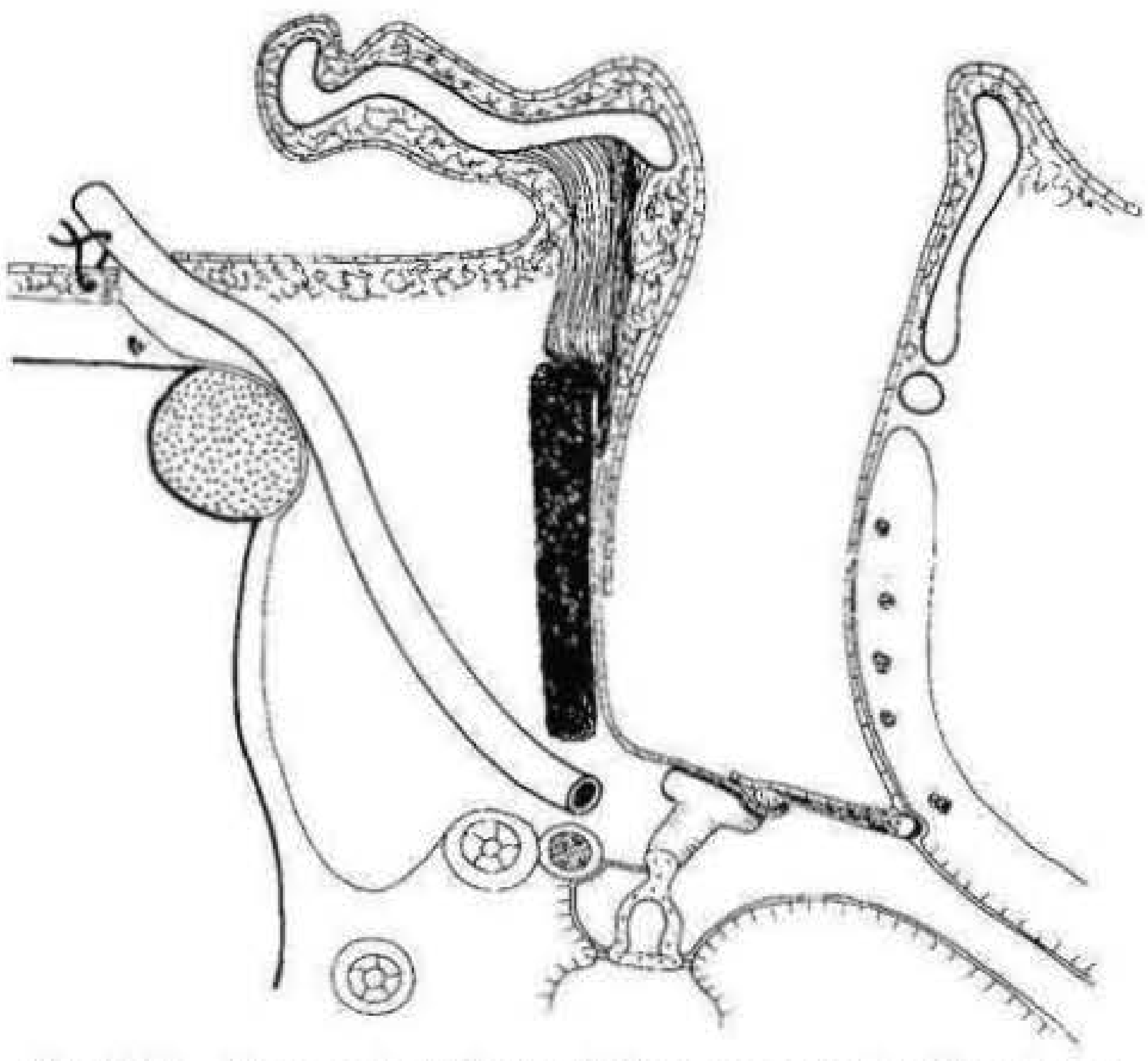


Fig. **849** **Reconstruction of the ear canal with glass ionomer cement** (Geyer and Helms). The shaped piece of cement is fixed in the proper position on the superior wall of the cavity and facial ridge. A Palva flap is placed on the meatal side of the cement graft. Medially, the cement is covered with perichondrium. A tube is placed in the aditus ad antrum

Biocompatible Glass Ceramic Material

Ceravital has been used in some centres for ossicular reconstruction. Reck (1985) used Ceravital (produced by Xomeed, Jacksonville, Florida) to reconstruct the ear canal and reventilate the cavity. Few other surgeons have used this material (Zöllner and Büsing 1986).

Bioglass and Ceravital protheses have the disadvantages of being nonporous materials, and are less easy to drill into specific shapes. The material has been more or less abandoned.

Glass Ionomer Cement

Complete or partial reconstruction of the ear canal wall with ventilation of the cavity using glass ionomer cement (Ionos, Seefeld, Germany) was carried out by Geyer and Helms (1992) on 57 ears after canal wall–down mastoidectomy. Using a retroauricular approach, a Palva flap is first elevated; this is to cover the cement on its meatal side (Fig. **849**). The cement is activated, after a canal wall–down mastoidectomy, preparation of ear canal skin flaps, ossiculoplasty with a glass ionomer cement prosthesis, and myringoplasty with perichondrium. The cement is premolded to serve as an ear canal wall, and then placed between the roof and the floor of the auditory canal. The cement hardens, and can be neatly fixed in place, making direct contact with the adjoining bone. Two silicone tubes are temporarily placed in the central attic region to serve as spacers, ensuring communication between the newly created cavity and the tympanic cavity (Fig. **849**).

It has however, been questioned whether covering this allogenous material with perichondrium alone is sufficient. Ear canal granulation may result, and late results are therefore needed.

Hydroxyapatite

The ear canal wall can be reconstructed with porous hydroxyapatite ceramic. This material has a macroporosity of 30% and a microporosity of less than 5%. The size of the micropores is approximately 3 µm. Three sizes of hydroxyapatite ear canal wall are available, varying in length from 17 mm to 21 mm. Grote uses the following technique (Grote and Blitterswijk 1986). After a retroauricular incision, a periosteal flap based on the cranium is elevated. The cavity is entered by mobilizing a concha-based skin flap. The flap is retracted outward, providing a good view of the cavity. Ear canal skin flaps are created superiorly and inferiorly. The superfluous cavity skin is removed, the mastoid cavity is cleaned,

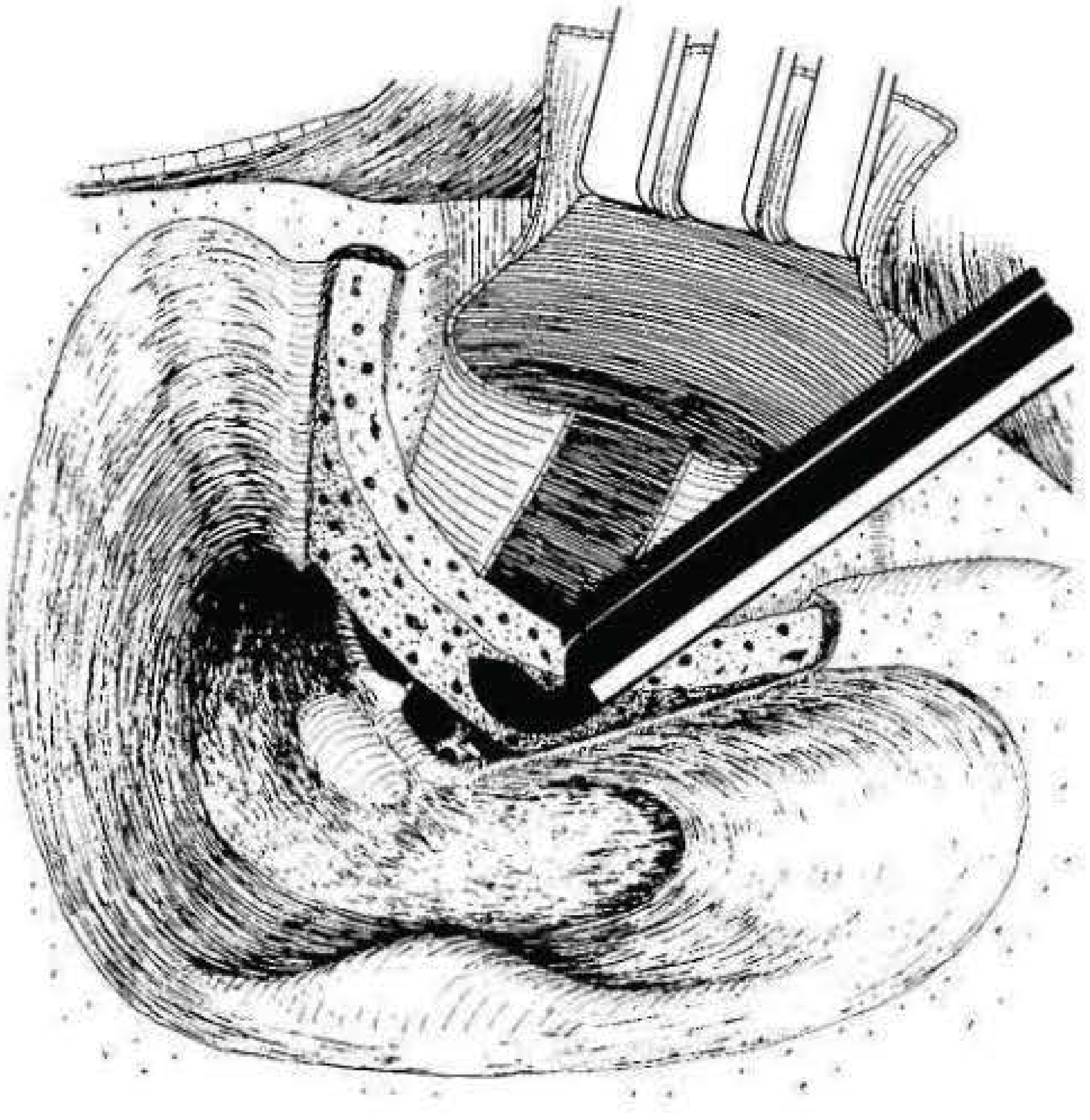


Fig. **850** **Reconstruction of the ear canal wall with hydroxyapatite implant** (Grote). The ear canal skin from the superior and inferior parts of the cavity, including the facial ridge, is elevated, creating superior and inferior skin flaps. The lateral skin flap is prepared and elevated. After creation of superior and inferior grooves on the cavity walls, the hydroxyapatite implant is inserted, providing an extensive connection between the tympanic cavity and the mastoid cavity

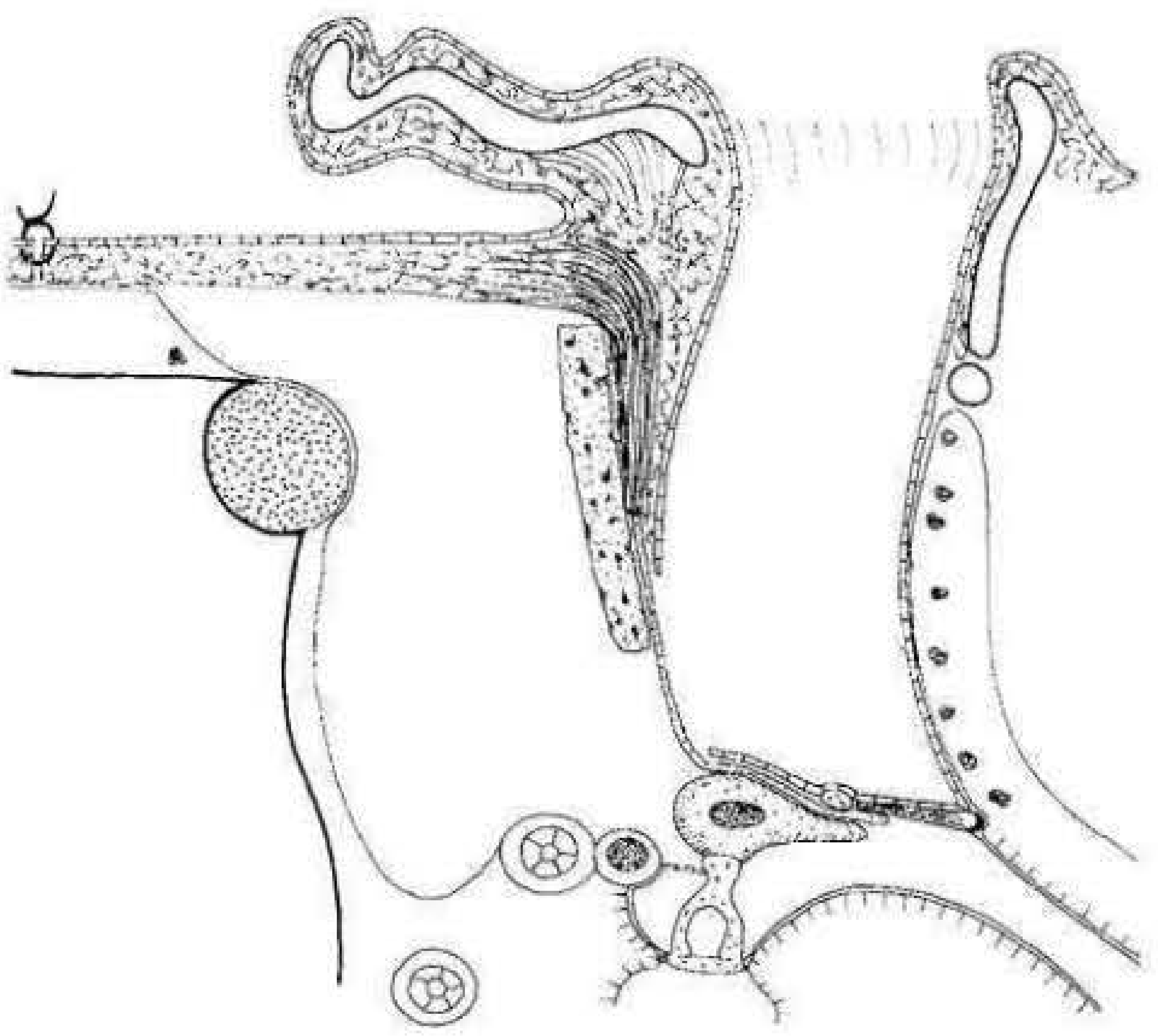


Fig. **851** Side view of the ear canal with a hydroxyapatite implant in place. The meatal side of the implant is covered with a large piece of fascia, which continues under the drum as an underlay graft. Laterally, the meatal side of the implant is covered with a mesenchymal tissue graft

and the tympanic cavity is prepared for reconstruction. Two grooves are made, one superiorly in the zygomatic root, and the other inferiorly along the facial ridge. Using a diamond burr, the hydroxyapatite ear canal wall is drilled to the exact length required. Along the facial ridge, the ear canal has to be shaped individually. Grote uses special instruments to measure the length and depth of the ear canal. The hydroxyapatite ear canal wall is placed in the grooves (Fig. **850**), providing a large tympanic isthmus. The ossiculoplasty is performed, and the drum is reconstructed with a large vein or fascia as an underlay graft, also covering the meatal surface of the hydroxyapatite. The musculoperiostal flap is placed on the meatal side of the hydroxyapatite (Fig. **851**). The laterally based epithelial flap is replaced, as are the inferior and superior ear canal skin flaps, and the cavity is packed.

In 30 patients with preoperative dry cavities reconstructed using this technique, no extrusions were found 3½ years after surgery. The meatal aspect of the hydroxyapatite was lined by epithelium, and the mastoid cavity was aerated in most cases. The reason for the good ventilation is that the new ear canal wall is placed laterally and posteriorly, allowing the tympanic membrane to be placed more laterally, which gives a widely opened tympanic isthmus and prevents obliteration of the tympanic cavity. It is important to cover the hydroxyapatite with a periosteum–subcutis flap and to have healthy cavity epithelium.

The porous type of hydroxyapatite is recommended for canal wall reconstruction where tissue penetration is desirable. In hydroxyapatite prostheses, the ingrowth and remodeling capacities have been experimentally documented. The dense type of hydroxyapatite is most suitable for ossicular reconstruction (Hörmann and Donath 1987, Lenis 1990), where tissue penetration should be minimized.

Precise reconstruction using the hydroxyapatite ear canal wall implant requires considerable reshaping of the prostheses, resulting in delay and occasionally breakage, and Black therefore (1991) recommends using a thin aluminum foil template to obtain a precise fit. After preparation of the cavity, a deep groove is made in the root of the zygoma to allow the implant to engage deep into the bone for stability and to avoid retractions. The aluminum foil is cut to size, then molded to cover the convex surface of the required wall. The curved foil is trimmed with scissors until the shape that precisely fits the canal wall defect from the anterior attic to the facial ridge is obtained. The curved template is placed over the implant, and the latter is drilled to the appropriate shape. The implant is then placed in situ, and any final adjustments are made. The small defects are sealed with bone paté. The implant can also be stabilized with hydroxyapatite fragments or bone chips. The meatus is lined with fascia or periosteal flaps, and is covered with the previously preserved cavity lining skin flaps.

Recognizing that the hydroxyapatite ear canal wall has to be covered on both sides — the meatal side and the mastoid side — with well vascularized autogenous tissue, and that previous techniques based on free grafts or on local flaps are of suspect vascular adequacy, Black and Kelly (1994) recently published a method of revascularization of the underlying grafts. They suggested a temporal pericranial flap, which introduces a vascular supply directly to the site of the canal wall defect.

The new vascular supply is provided by a superiorly based pericranial flap consisting mainly of periosteum deep to the temporal muscle, and including the middle temporal artery (Fig. **852**), which is a branch of the internal maxillary artery. The size of the flap can be adjusted according to the extent of the canal wall, but normally extends about 4 cm above the linea temporalis to allow for some retraction. The flap can be combined with a Palva flap, if desired.

After a posteriorly-based retroauricular incision through the subcutaneous tissue and along the lower border of the temporalis muscle, a Palva flap is elevated and held in place with a selfretaining retractor (Fig. **852**). The periosteum is then carefully elevated from the mastoid plane posteriorly. After elevation of the temporalis muscle, the periosteal incision is continued superiorly, demarcating a flap, which includes the middle temporal artery (Fig. **853**). The flap is elevated and pushed with a periosteal elevator in an inferior direction (Fig. **854**), resulting in a large periosteal flap with some attached fibers of muscular tissue and the temporal vessels. The hydroxyapatite flap is placed in the grooves as described previously, and after tympanoplasty and ossiculoplasty, the drum perforation

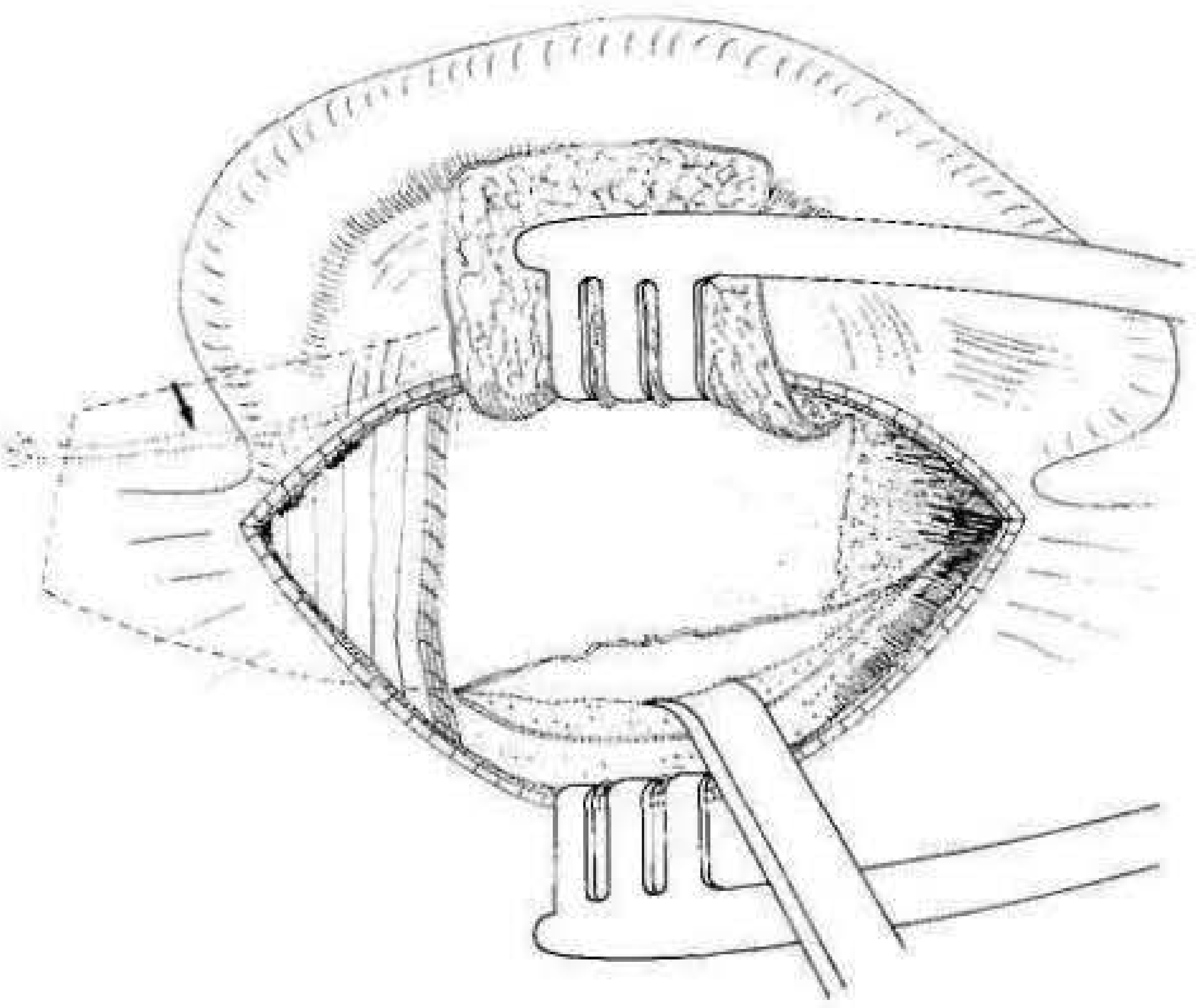


Fig. **852** **Reconstruction of the ear canal wall with a hydroxyapatite implant** supported by a periosteal flap vascularizing the canal wall repair (Black and Kelly). After a retroauricular incision, a Palva flap is elevated without adjacent periosteum. An incision is made in the periosteum, which is elevated. The dashed line indicates the incision of the periosteum under the temporalis muscle to create a periosteum flap that includes the middle temporal artery (arrow)

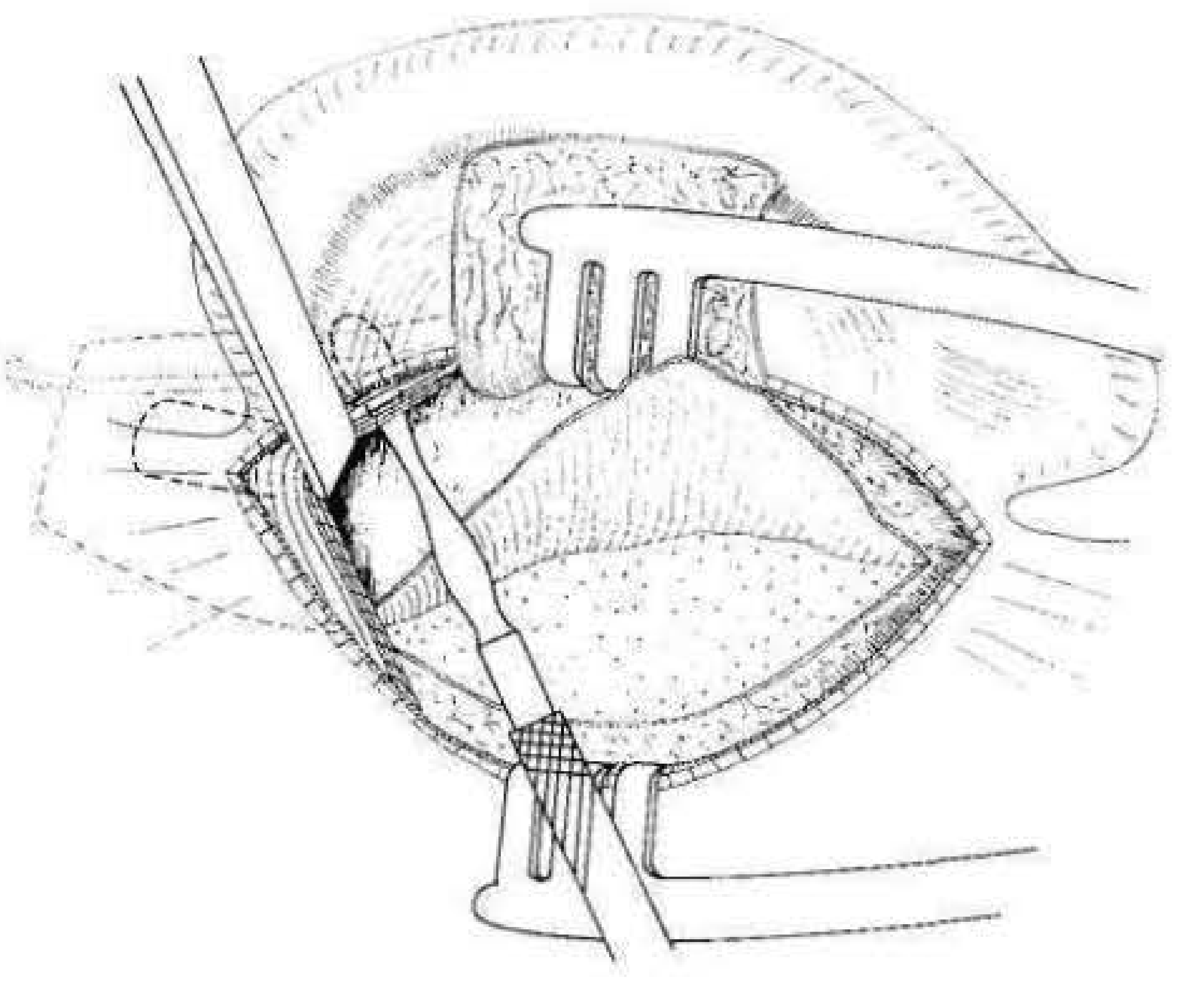


Fig. **853** The periosteum from the mastoid plane is elevated. The temporalis muscle is elevated with a large retractor, and the periosteum is incised along the dashed line

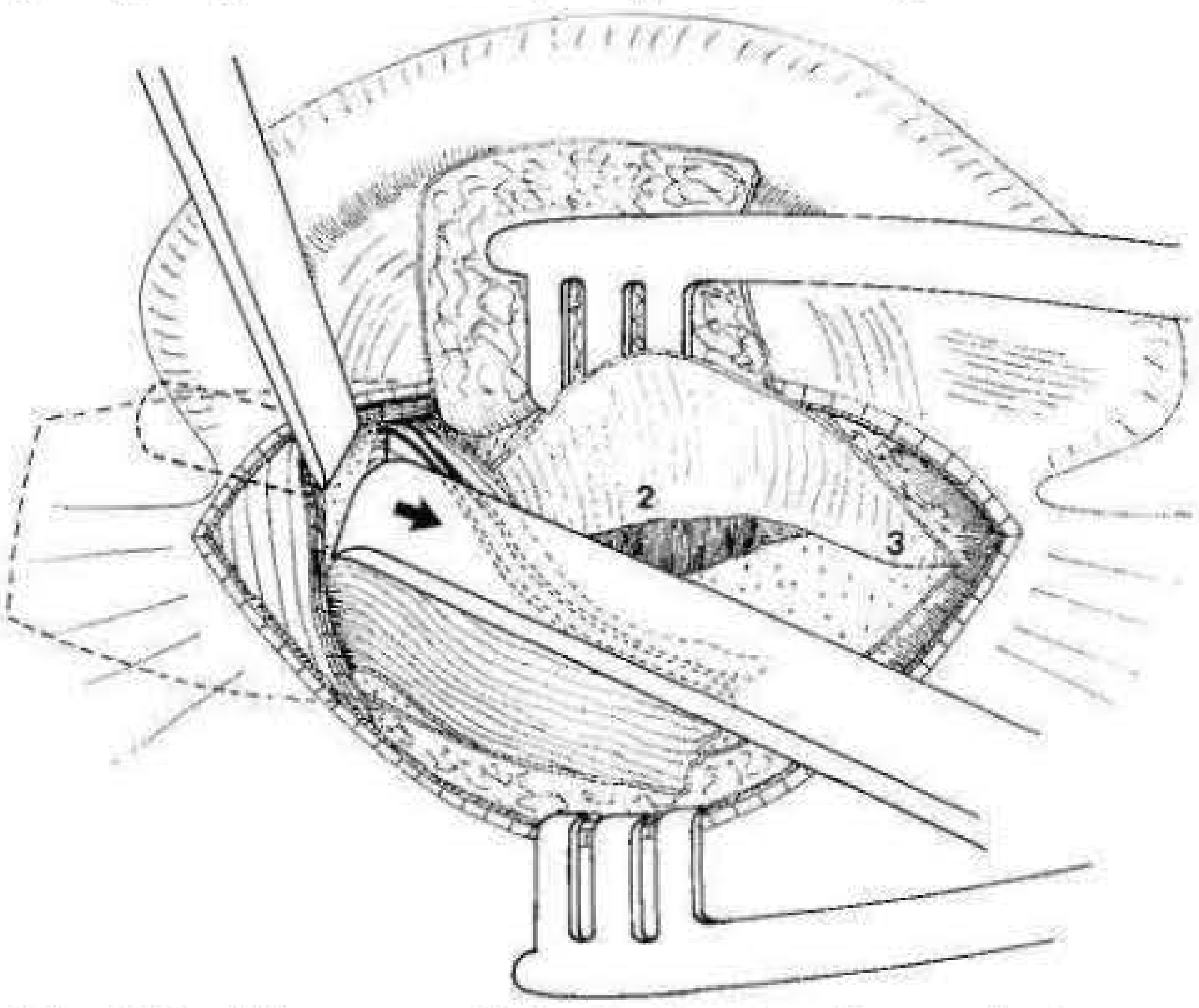


Fig. **854** Using a periosteal elevator, the periosteum under the temporalis muscle is elevated and pulled in inferior direction (arrow), resulting in a large periosteal flap based superoanteriorly (1), anteriorly (2), and inferiorly along the pinna (3)

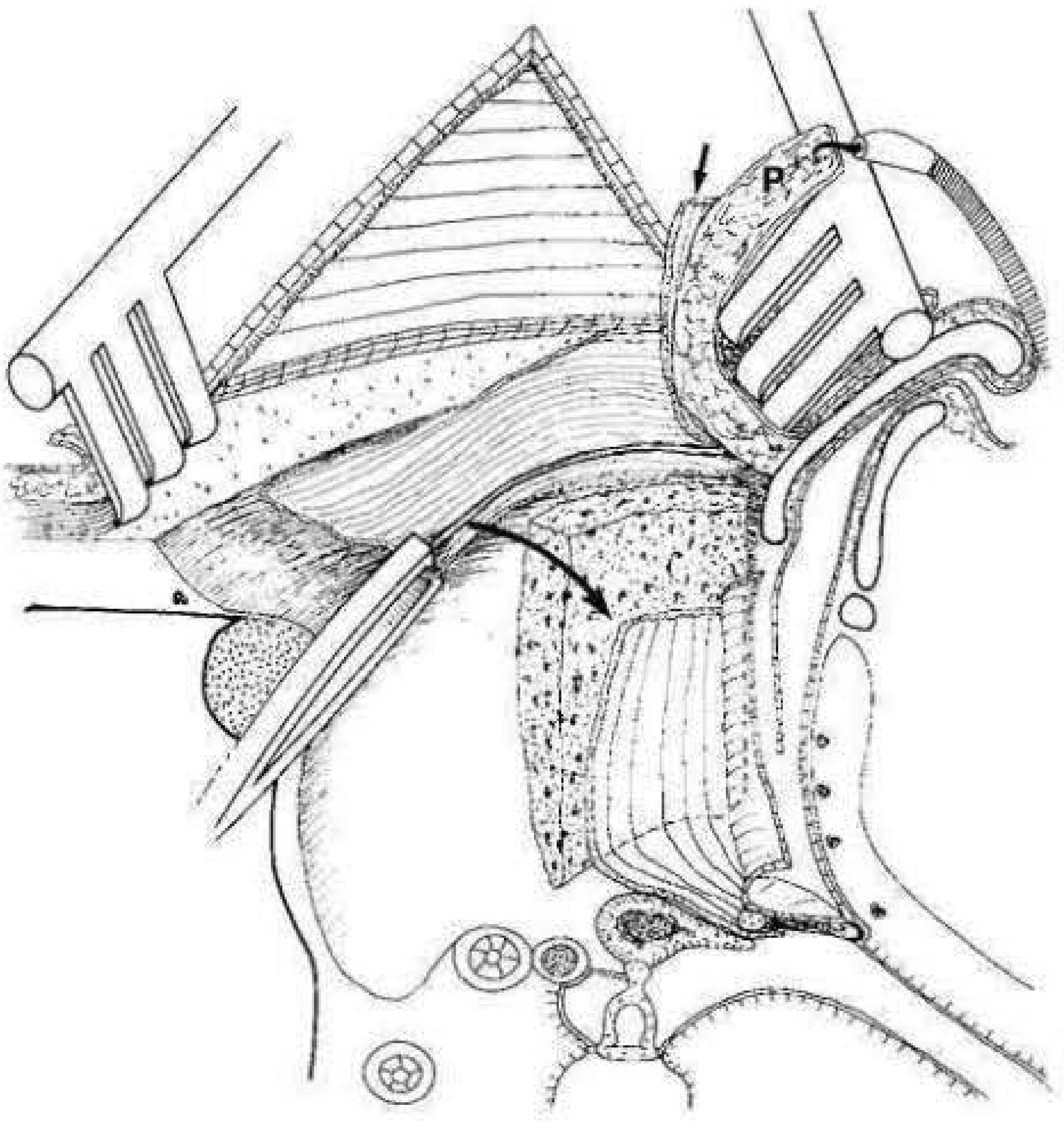


Fig. **855** Side view with some perspective of the reconstruction of the ear canal with hydroxyapatite. An ossiculoplasty is performed. The drum perforation is covered with a fascia as an underlay graft. It also continues onto the medial half of the hydroxyapatite graft. The periosteal flap is to be placed onto the meatal side of the hydroxyapatite under the fascia (curved arrow). The Palva flap (P) will be placed on the mastoid side of the hydroxyapatite graft, and the periosteum from the mastoid plane (small arrow) on the meatal side

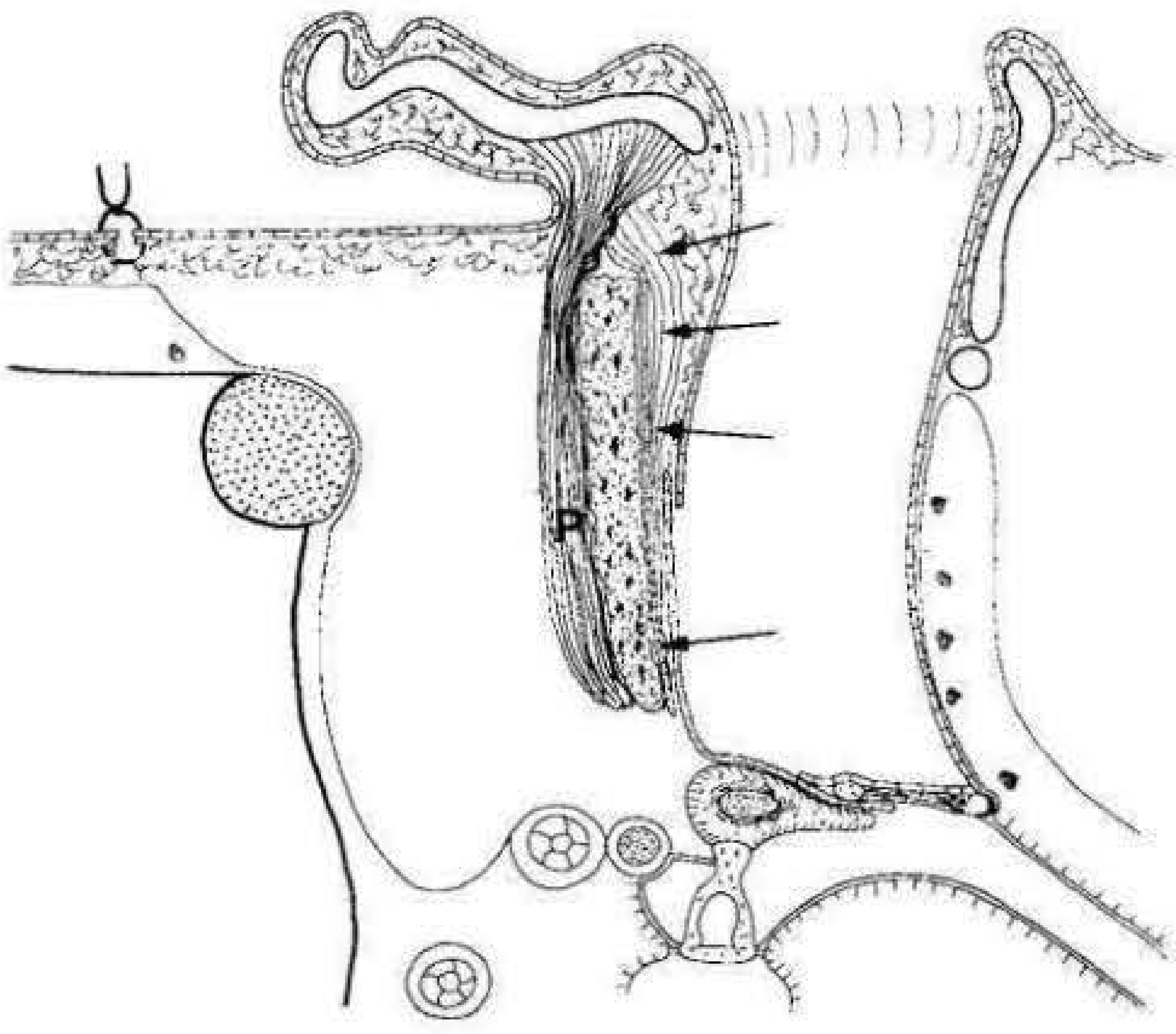


Fig. **856** **Side view of the final position of the flaps:** fascia or perichondrium covering the perforation and the medial part of the hydroxyapatite implant. The periosteal flaps (arrows) cover the meatal side, and a Palva flap (P) covers the mastoid side of the hydroxyapatite implant

is closed with an underlay fascia graft extending over the medial half of the hydroxyapatite ear canal graft (Fig. **855**). The periosteal flap is pulled anteriorly to cover the entire meatal surface of the graft, and finally the Palva flap is placed on the mastoid side (Fig. **856**).

The technique of harvesting this flap is similar to the technique the author has used in harvesting periosteum in a retroauricular approach, described in Vol. 1 (Figs. **300–307**), the only difference being that the periosteum flap is used as a free graft, in contrast to the Black technique, where it is pedicled anterosuperiorly. The Black technique is an improvement on other reconstruction methods, because additional autogenous tissue is introduced. In the Black technique, the fascia can be harvested from the outer layer of the temporalis muscle and the periosteum, as well as the Palva flap, can be raised from the mastoid process and under the temporalis muscle region. Finally, the temporalis muscle flap can also be used if obliteration is needed. It is true that the small vessels of the middle temporal artery supplying the periosteal flap can be damaged while it is being elevated, but more important is the fact that a large periosteal flap covers the meatal side of the hydroxyapatite with the Palva flap on the mastoid side (Figs. **855, 856**). This is in contrast to the Grote technique, which has no covering at all on the mastoid side, and very little covering on the meatal side (Fig. **851**).

Black uses a small perichondrium–cartilage graft instead of bone paté, as described previously, in order to close the small fissure between the drum and the ear canal. After replacing the ear canal skin flaps, the ear canal is packed with fine Silastic strips.

In Black's series of 62 cases after an average follow-up of 18 months (five months to four years), prior to the introduction of the vascular strip the dehiscence rate of hydroxyapatite wall implants was 10%. Subsequent to the use of the periosteal flap, no dehiscence occurred, but three implants were removed due to immediate or delayed infection.

The characteristic feature of all of the methods of ear canal wall reconstruction with ventilation is that the results are based on small series and short observation periods. Usually, the methods using allogenous materials (e. g., septal and knee cartilage, ear canal wall, lyophilized dura) and biocompatible materials have been used by their inventors alone, and these methods are still waiting to be confirmed by other surgeons. However, the techniques of reconstruction using autogenous tissues described can be used in connection with obliteration. A proper ear canal wall reconstruction is always an important part of any obliteration.

Partial Reconstruction of the Ear Canal Wall

Partial reconstructions of the ear canal wall include methods of reconstructing the bony bridge or attic walls in order to elevate the tympanic cavity and ventilate the attic after a canal wall–down mastoidectomy. The partial reconstruction methods for the ear canal wall can be divided into four subgroups:

1. *Reconstruction of the entire attic,* i. e., its lateral and posterior walls, performed either with bone (Portmann 1966) or with autogenous tragal or conchal cartilage, allogenous septal, costal, or knee cartilage, or with hydroxyapatite. The attic is converted into a closed cavity communicating widely with the tympanic cavity.

After a canal wall–down mastoidectomy (Fig. **857**), or in the situation with an old radical cavity, a groove is drilled along the mastoid tegmen at the level of the bridge to allow a specially shaped piece of cortical bone to rest firmly on its bony edge. The inferior end of the bony plate is placed on the facial ridge. The lateral attic is thus aerated (Fig. **858**), and the attic is closed at the antrum with one or two small pieces of cortical bone. After ossiculoplasty, the reconstructed attic walls are covered with the same fascia as is used for the myringoplasty, continuing onto the mastoid tegmen, the medial wall of the antrum, and over the facial ridge (Fig. **859**).

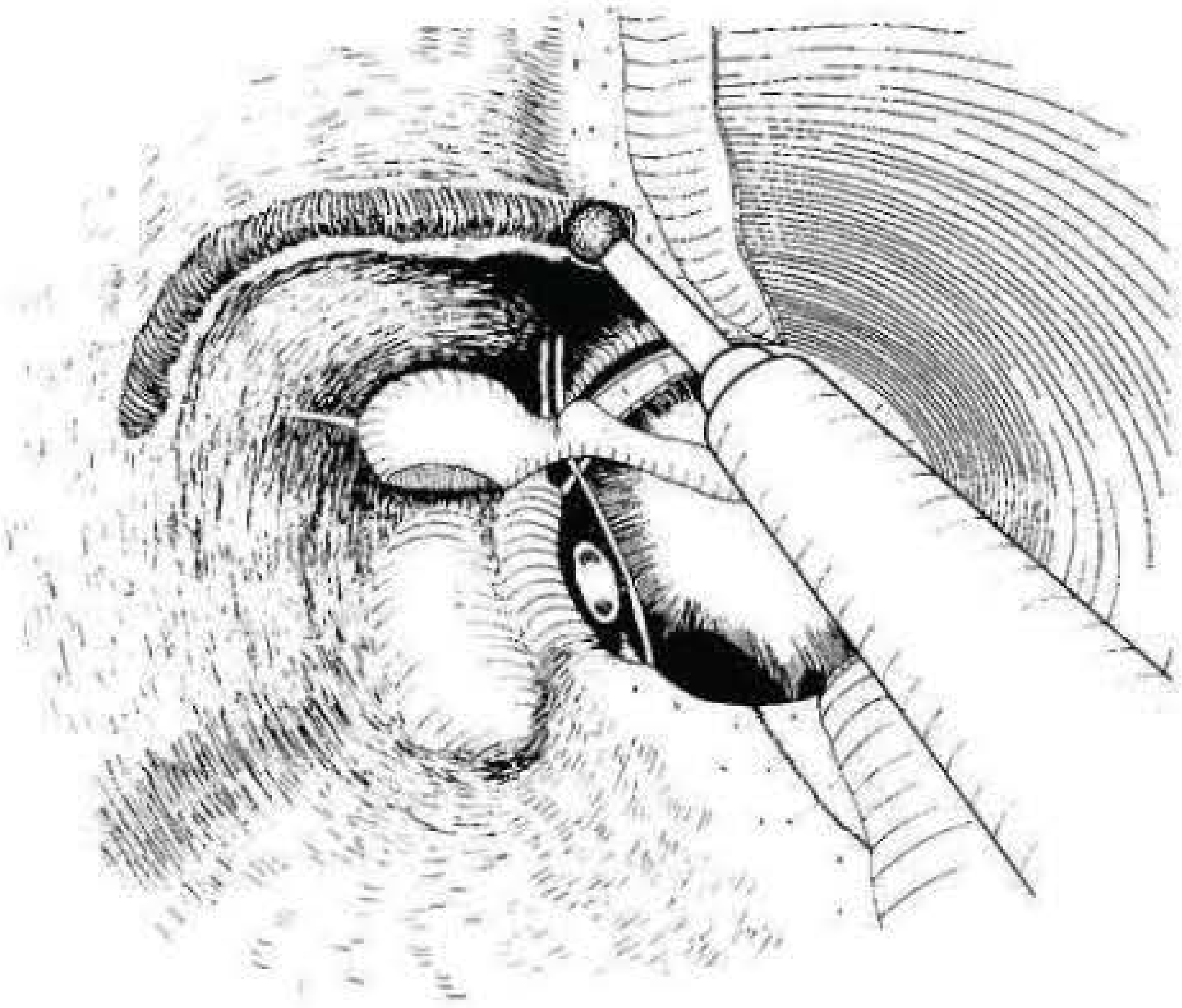


Fig. **857** **Reconstruction of the entire attic** (Portmann 1966). After a canal wall–down mastoidectomy with an intact malleus, total perforation, and absent stapes suprastructure, a groove is drilled along the mastoid tegmen, creating a step

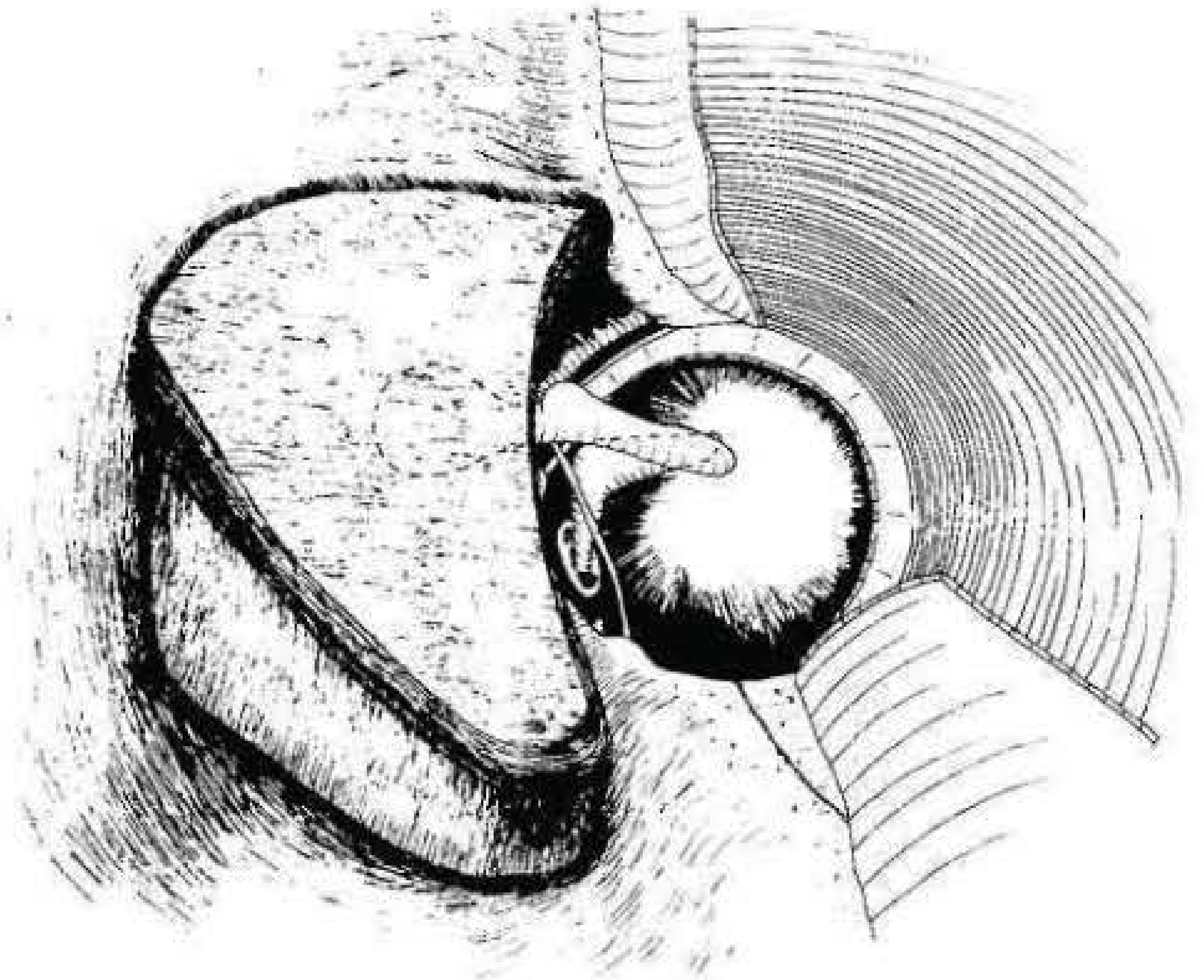


Fig. **858** A piece of shaped cortical bone is placed on the step that has been created at the mastoid tegmen, and inferiorly on the facial ridge. Posteriorly, the attic is closed with another piece of cortical bone. A columella is placed between the footplate and the malleus handle

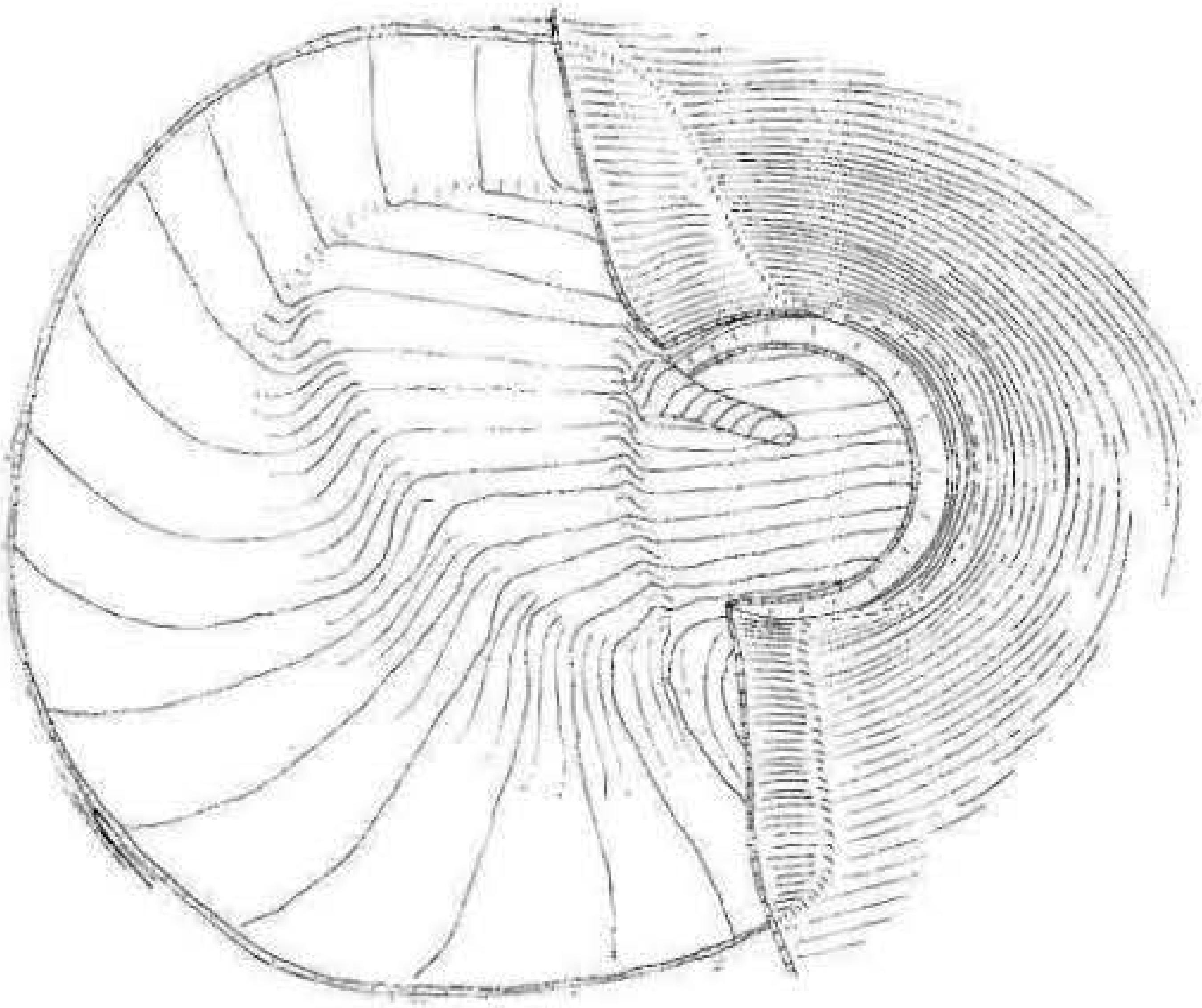


Fig. **859** The fascia covers the total perforation as an underlay graft, and continues over the reconstructed lateral attic wall onto the mastoid tegmen, the medial wall of the antrum, and the facial ridge

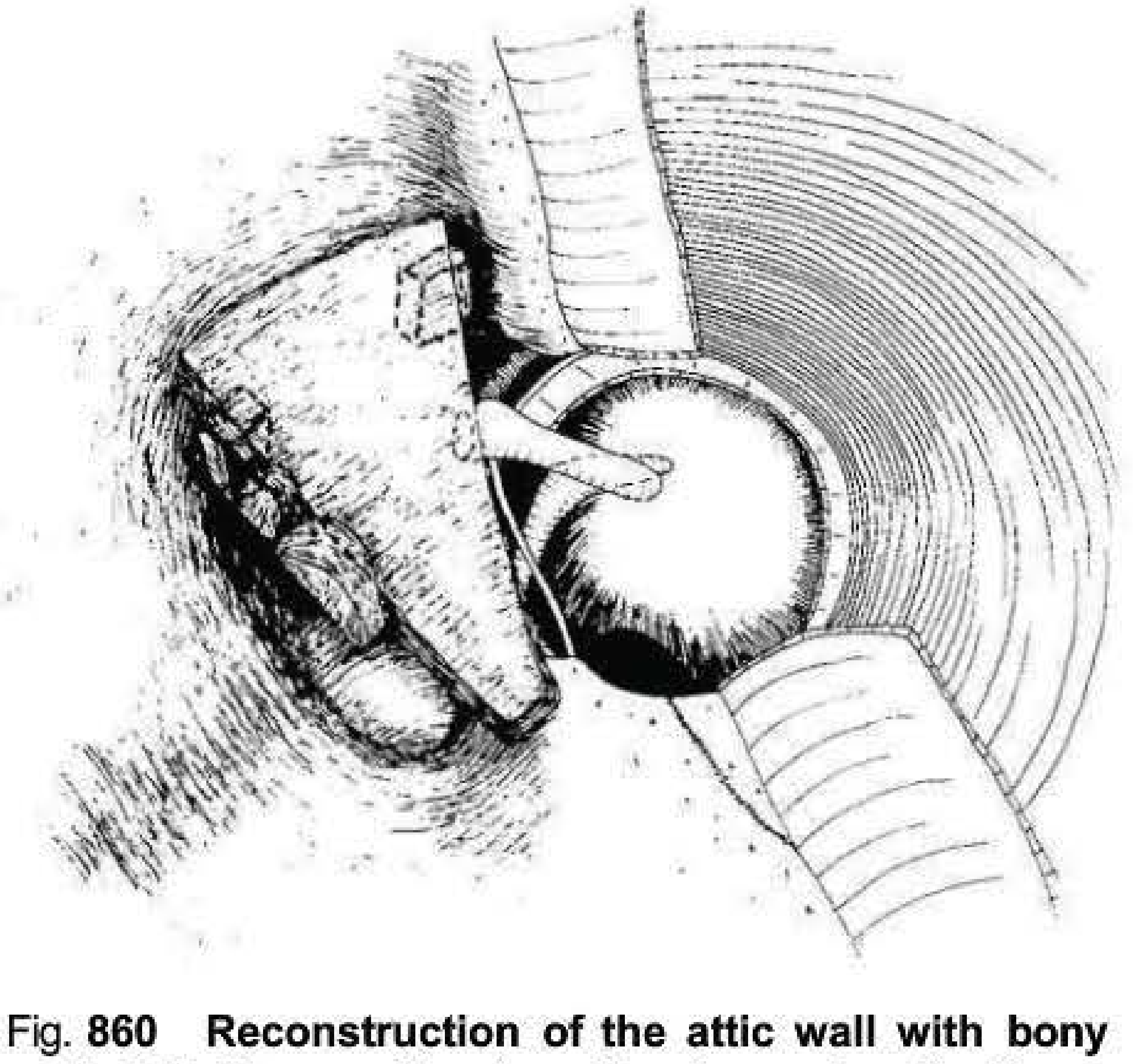


Fig. **860** **Reconstruction of the attic wall with bony pedestals.** Two small rectangular pieces of cortical bone (dashed) are placed along the tegmen tympani. A large piece of cortical bone is placed on these two pieces and on the facial ridge. The posterior wall of the attic is covered with small pieces of cortical bone

Instead of grooves as suggested by Portmann (1966) the author has used another reconstruction of the attic: Two small rectangular pieces of cortical bone are placed as "pedestals" along the tegmen tympani, creating support for the lateral attic wall, which is placed on the "pedestals" and the facial ridge. Several small bone chips close the attic posteriorly (Fig. **860**).

Cartilage is particularly well suited for the reconstruction of the attic (Fig. **861**) using the principles described by Heermann (1962, 1992).

2. *Reconstruction of the bridge* using cortical bone (Portmann 1966) or tragal cartilage (Szpunar 1973) in order to ventilate the attic. Using a diamond burr, a small groove or step is drilled into the superior attic wall, close to the zygomatic root, at the level of the original bony bridge. A piece of cortical bone or tragal cartilage is placed in the groove and then onto the facial ridge (Fig. **862**).

3. *Elevation of the medial attic wall,* by placing a piece of cortical bone onto the medial wall of the attic (Bauer 1966). The piece of bone is about 1–2 mm thick. It is placed over both the eminence of the lateral semicircular canal and the facial nerve, and is shaped in such a way that the distance to a

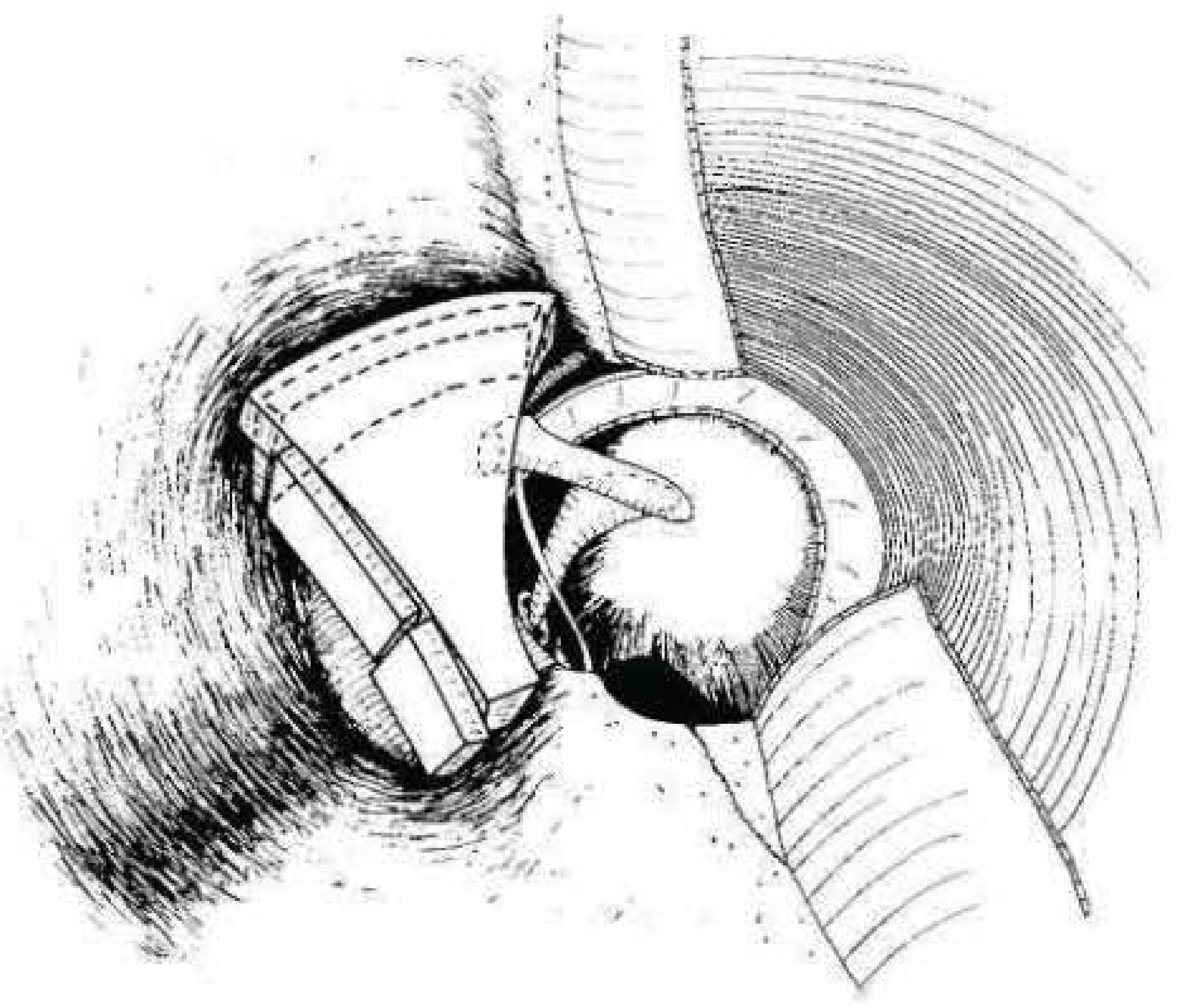


Fig. **861** **Reconstruction of the attic with autogenous conchal or tragal cartilage.** A strip of conchal cartilage is placed along the tegmen tympani (dashed). Another piece of cartilage is placed on this strip and on the facial ridge. The posterior part of the attic is covered with small pieces of cartilage. A columella is placed between the footplate and the malleus handle. The total perforation and the cartilage will be covered with an underlay fascia graft

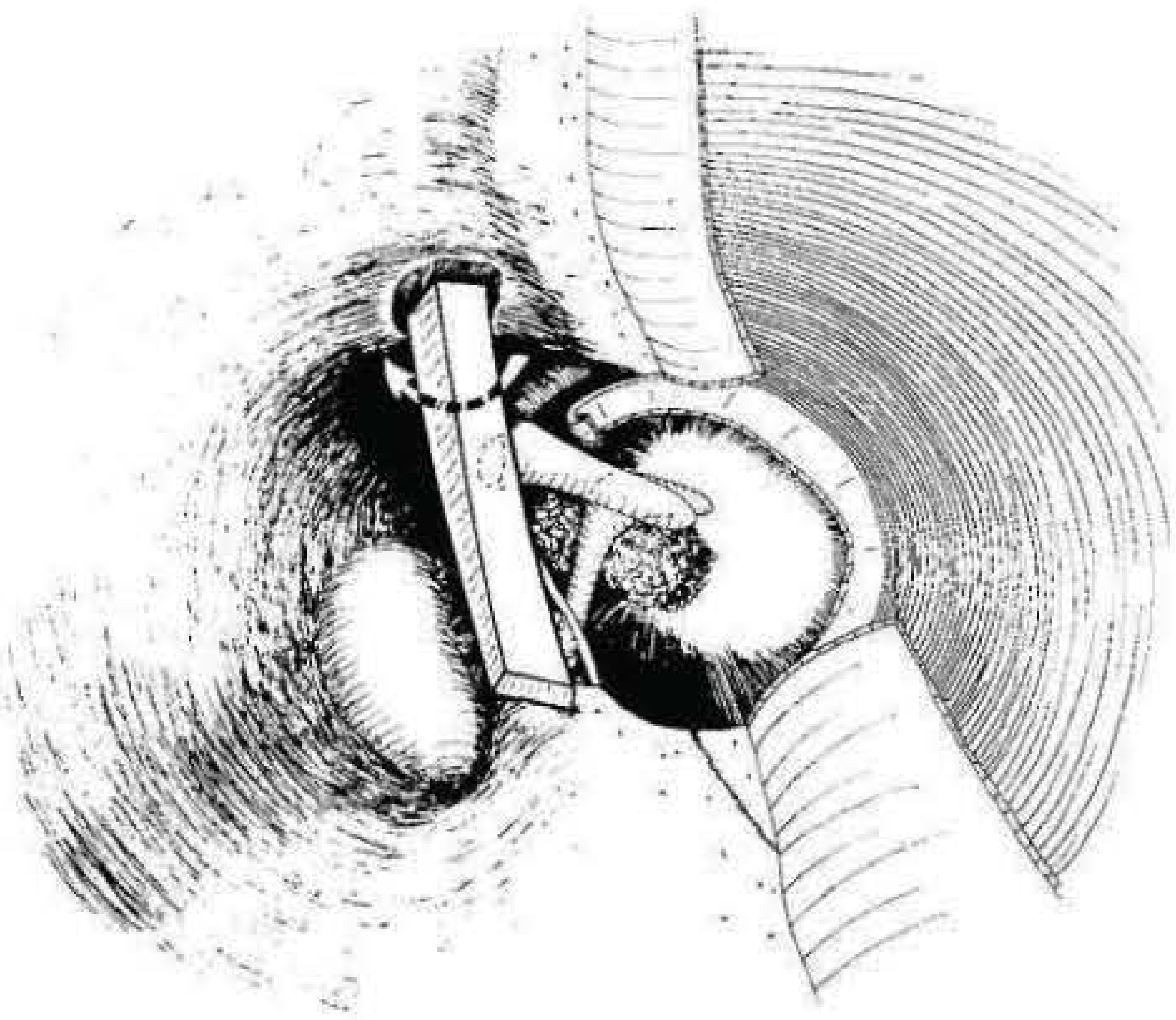


Fig. **862** **Reconstruction of a bridge in order to ventilate the attic** (Szpunar). In a canal wall–down mastoidectomy situation, a groove at the mastoid tegmen close to the zygomatic root is drilled, and a piece of tragal cartilage is placed in this groove or step and on the facial ridge. Ventilation of at least a part of the attic is desired (arrow). A columella is placed between the footplate and the malleus handle. The fascia will close the total perforation, cover the bridge, and then continue gradually down onto the medial wall of the cavity. The fascia can also continue laterally, in order to either obliterate or ventilate the cavity columella is large enough to avoid any contact and later bony fixation (Fig. **863**).

Palisades of autogenous tragal or conchal cartilage or suitable pieces of autogenous fibrous tissue (fascia or periosteum) can be used to elevate the medial attic wall. Strips of lyophilized dura have been used by some authors. The drum level is elevated, the risk of adherence to the drum is reduced, and the columella can be positioned in a more central region of the drum (Fig. **864**).

4. *Elevation of the medial attic wall by obliteration of the attic* using either several small pieces of autogenous bone (Fig. **865**) or palisades or pieces of cartilage (Fig. **692**), bone paste, or other obliteration materials. Elevation of a medial attic with smooth walls, without any risk of retraction is provided for. The mastoid cavity can be obliterated or left as an open cavity.

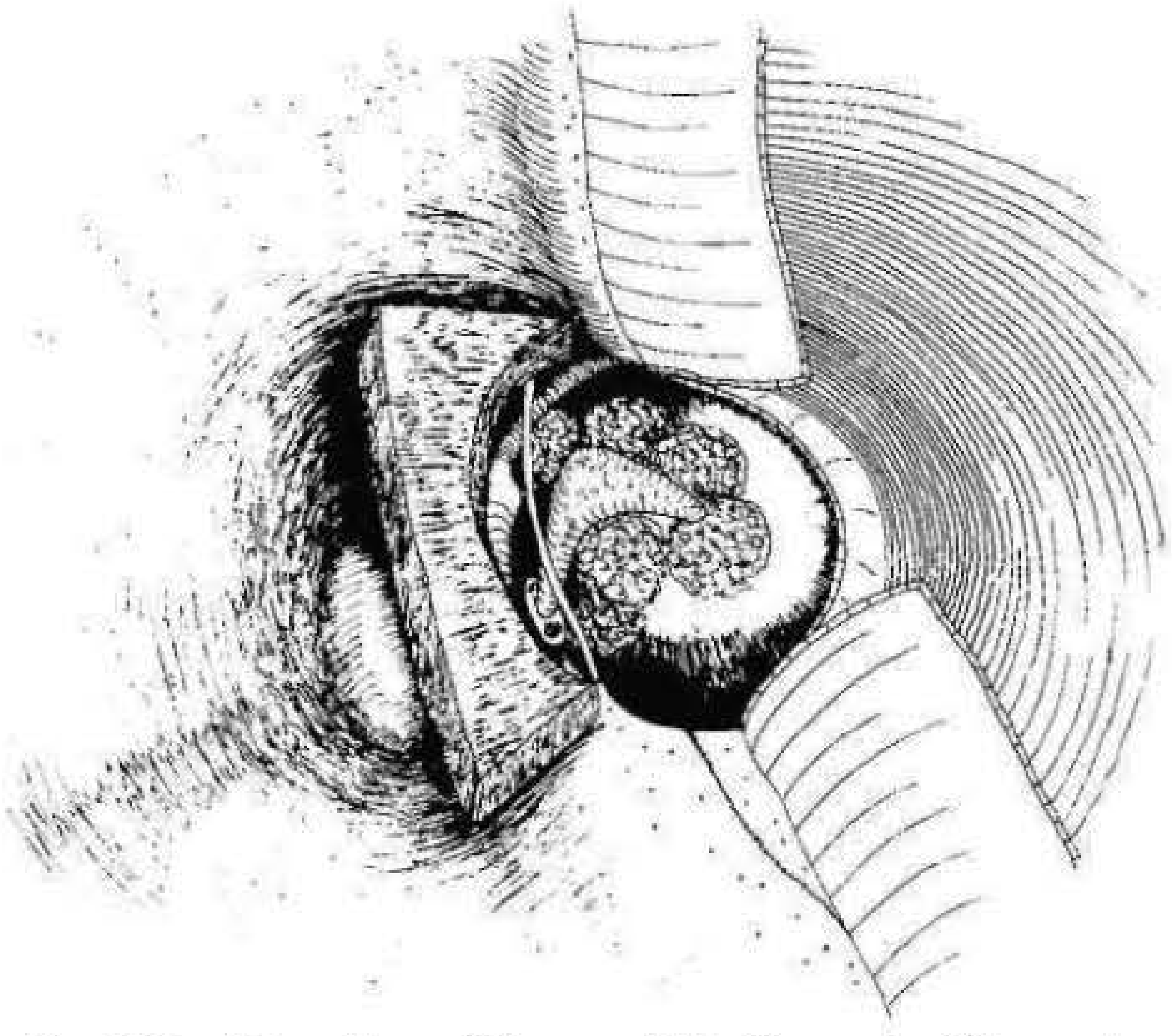


Fig. **863** **Elevation of the medial attic wall with a relatively thick, specially shaped piece of cortical bone** (Bauer) in a situation after canal wall–down mastoidectomy with total perforation and no ossicles. A columella is placed on the footplate, supported by Gelfoam balls. The cortical bone is placed on the eminence of the lateral semicircular canal and the facial nerve

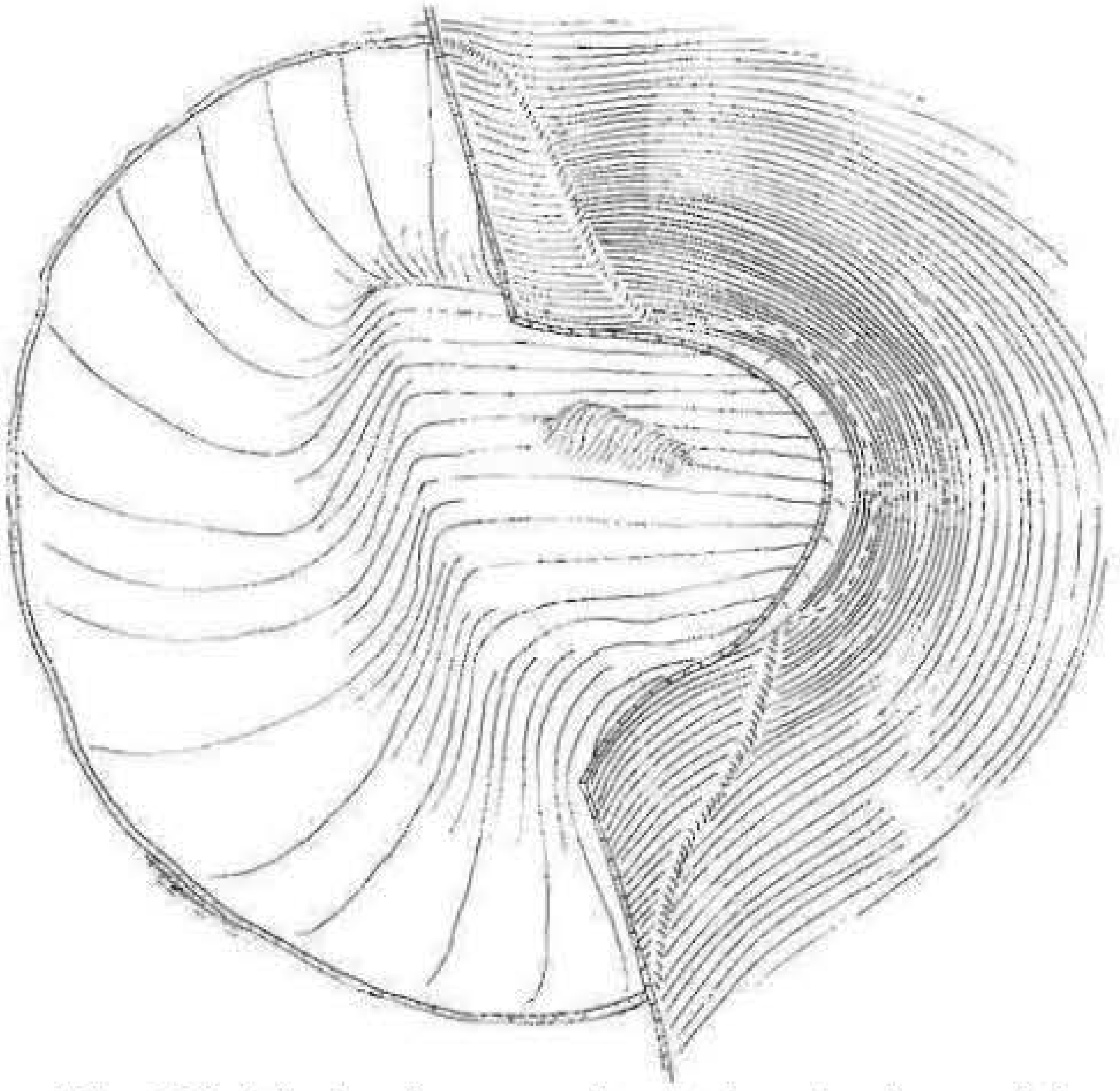


Fig. **864** The fascia covers the total perforation and the piece of bone as an underlay graft, and continues onto the medial antrum wall and the mastoid tegmen

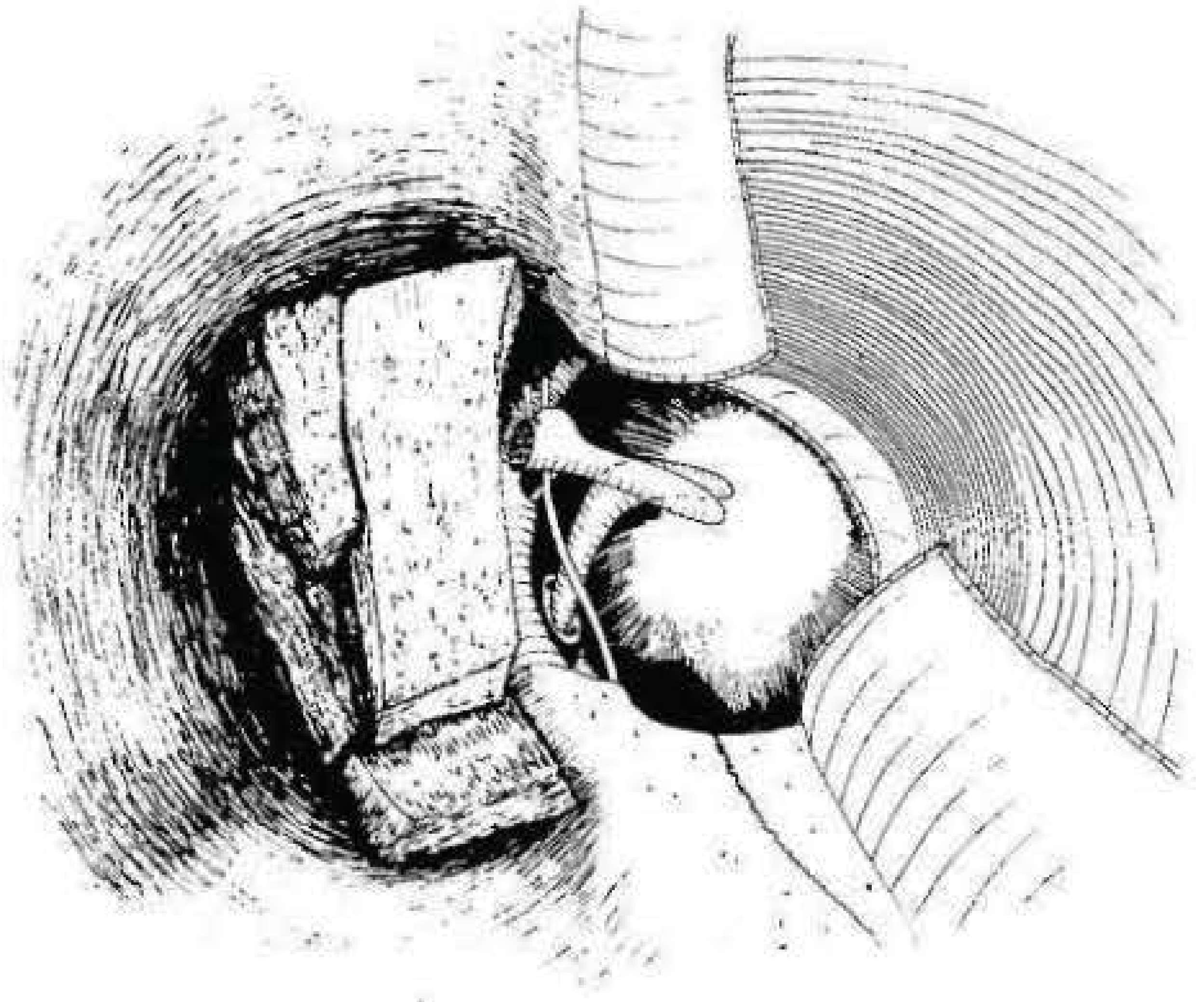


Fig. **865** **Obliteration of the entire attic** with small pieces of cortical bone, placed side by side. The columella is placed between the footplate and the malleus, and the fascia will cover the cortical bone and the total perforation as an underlay graft. It will continue toward the medial attic wall and mastoid tegmen

18 Obliteration of the Cavity with Pedicled Muscle Flaps

During the first half of the twentieth century, muscle–periosteal flaps were used for closure of retroauricular fistulas (Gabe 1911, Mayer 1917), for obliteration after simple mastoidectomy (Mosher 1911, Klestadt 1933), and sporadically for obliteration after the Barany radical mastoidectomy method without meatoplasty (Björlin 1925, Mill 1931, Kisch 1932, Popper 1935). During the late 1950s and 1960s, many methods of cavity obliteration and reconstruction of the ear canal wall muscle was introduced in connection with modern tympanoplasty methods. With the one exception of the free temporalis muscle (Heermann 1962), all other grafts have been pedicled. The various flaps used can be classified into superiorly based, anteriorly based, and inferiorly based flaps.

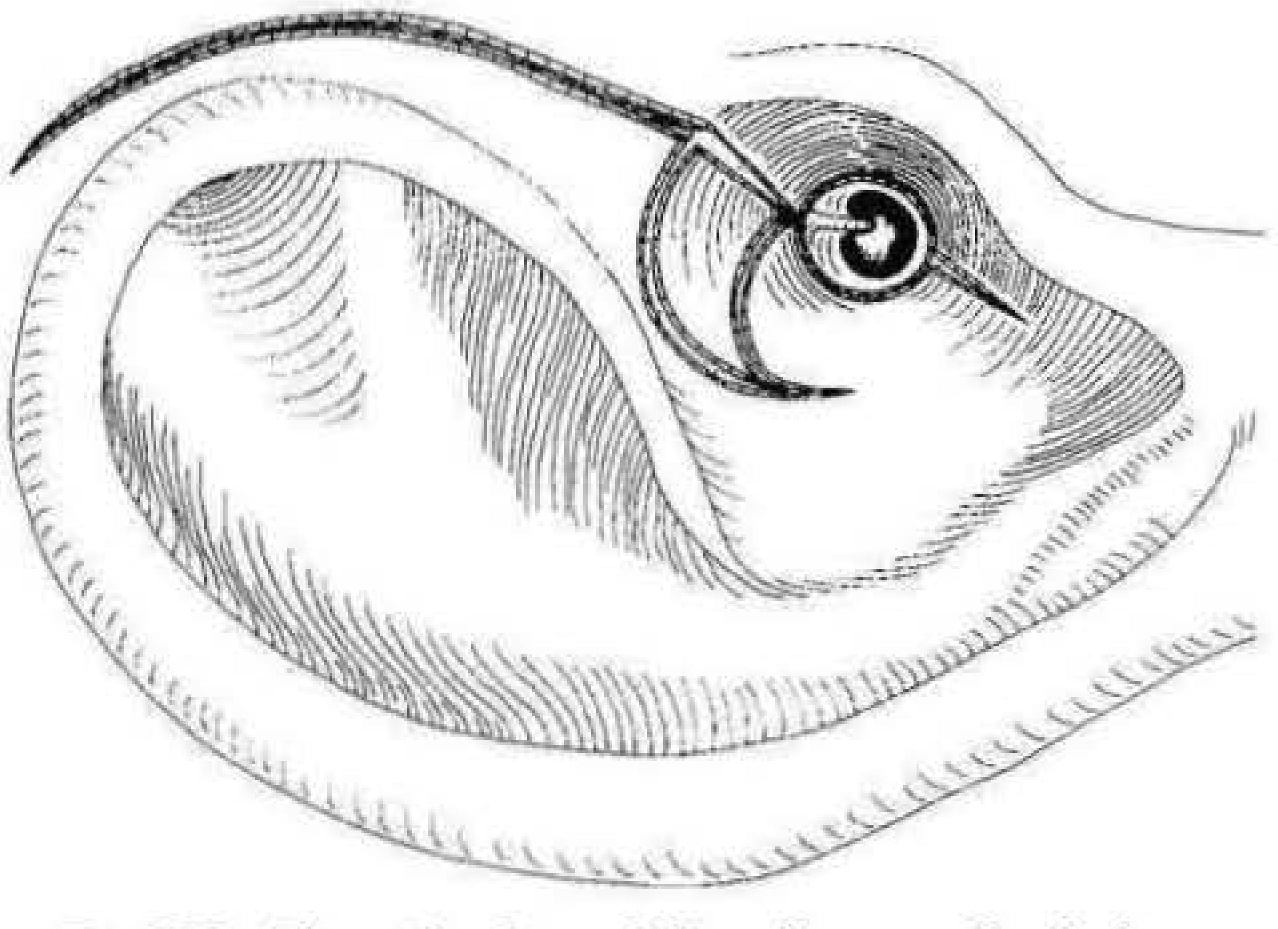


Fig. **866** **The Rambo obliteration method in an endaural approach.** The vertical incision extends up to the upper edge of the auricle, and the intercartilaginous incision runs medially to Shrapnell's membrane. A lateral circumferential and a medial circumferential incision connect the intercartilaginous incision. At the 5-o'clock position, a radial incision is made. Around the annulus, the skin is incised to remove the squamous epithelium from the drum. The posterior meatal skin is removed. It will be replaced at the end of the operation

Superiorly Based Flaps

The superiorly-based flaps usually consist of the temporal muscle, elevated together with the periosteum and the temporalis muscle fascia, and they are turned down into the cavity. Such flaps are usually sufficient to obliterate the upper part of the cavity. Flaps consisting partly or mostly of retroauricular subcutaneous fibrous tissue and muscle with its periosteum can be superiorly based, and several obliteration techniques have been described in endaural and retroauricular approaches.

In the early 1930s, Mill (1931) and Kisch (1932) used a temporal muscle flap in an attempt to obliterate the mastoid cavity and retain an external auditory canal.

The Rambo Flap

Rambo (1957) described a method of covering the tympanic cavity and the medial antrum wall with a superoanteriorly-based flap of temporalis muscle. The aim of the flap was to bridge the tympanic cavity and restore hearing.

After a special endaural incision, extending posterosuperiorly to the upper edge of the auricle (Fig. **866**), a large area of the temporalis muscle fascia is exposed. The conchal skin is elevated, creating an anterior and an inferior skin flap, and exposing the entire bony ear canal. The drum epithelium is removed (Fig. **867**). A conservative radical cavity is created, with extensive removal of air cells (Fig. **868**). A flap of the temporalis muscle with its fascia is cut, and it is turned down over the mastoid tegmen into the cavity to cover the drum remnant, the attic, and the medial wall of the aditus ad antrum (Fig. **869**). A larger flap will cover the tympanic cavity, the attic, and the medial wall of the antrum (Fig. **870**). The canal skin flaps are returned, and the free flap of canal skin is replaced, partly covering the muscle flap and partly covering the bone of the cavity (Fig. **871**).

The major part of the cavity wall is not covered with muscle. Rambo never used the muscle to fill the cavity, but the muscle contributes with its vascularity to healing and is a vascular support for skin flaps. In subsequent years, Rambo detached the drum from

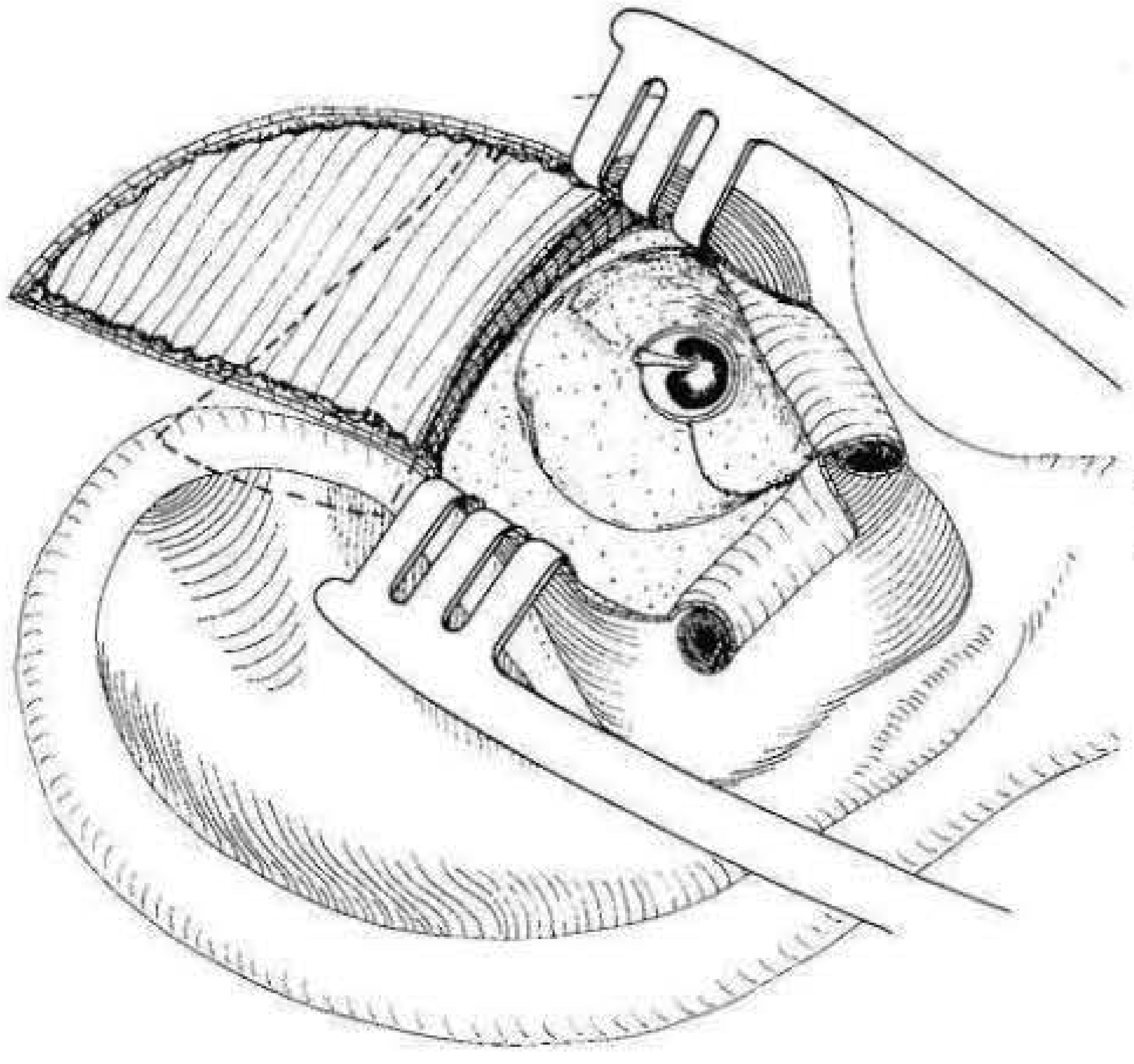


Fig. **867** The temporalis muscle fascia is exposed. The skin from the anterior and inferior parts of the ear canal is elevated as two laterally pedicled flaps. The epithelium from the drum remnant is removed. The incision in the temporalis muscle to harvest the flap is indicated by a dashed line

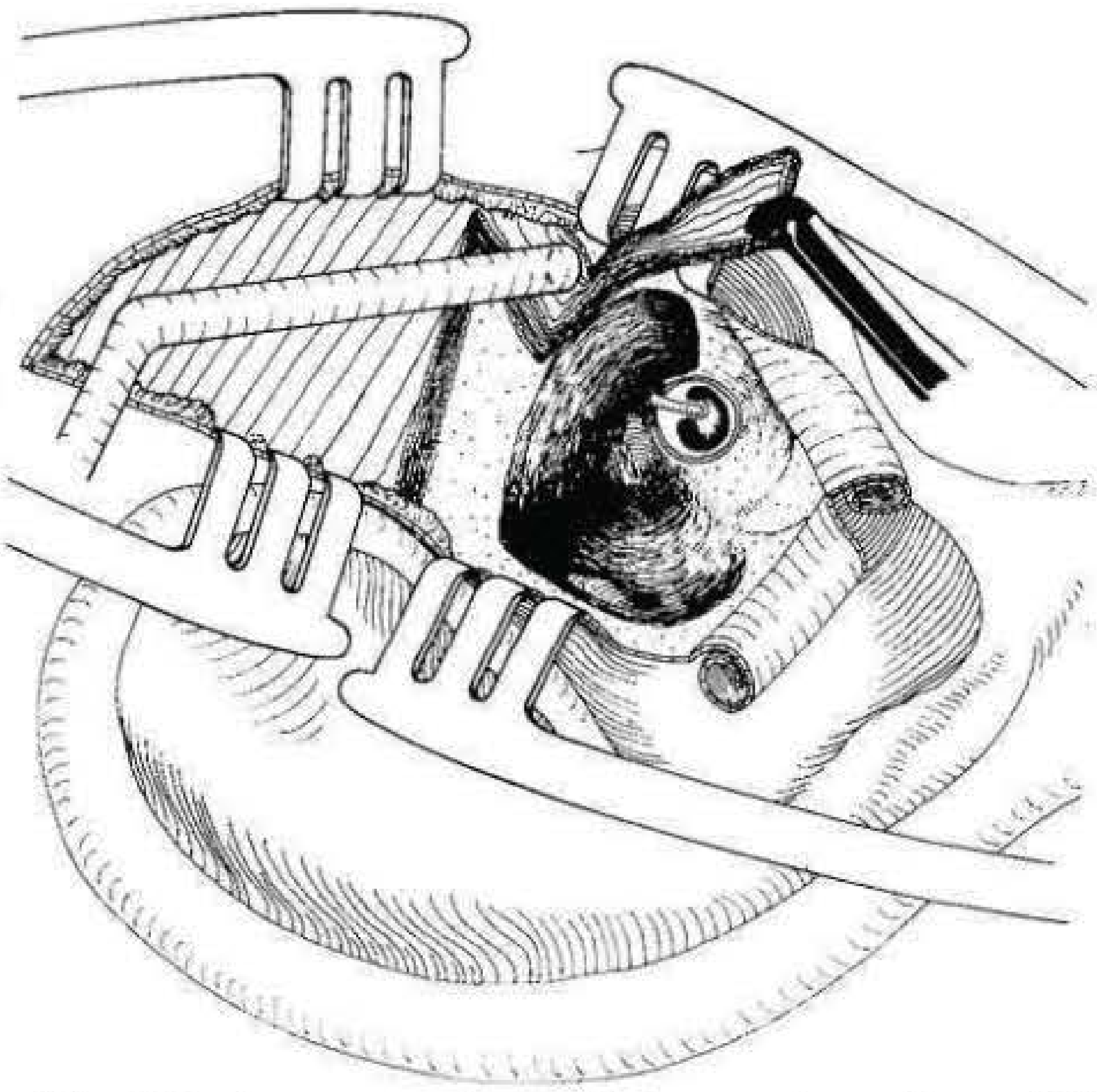


Fig. **868** A conservative radical operation with partial preservation of the bony bridge, resection of the malleus head, and extraction of the incus, is performed. An anteriorly-pedicled temporalis muscle flap is excised and pushed toward the cavity

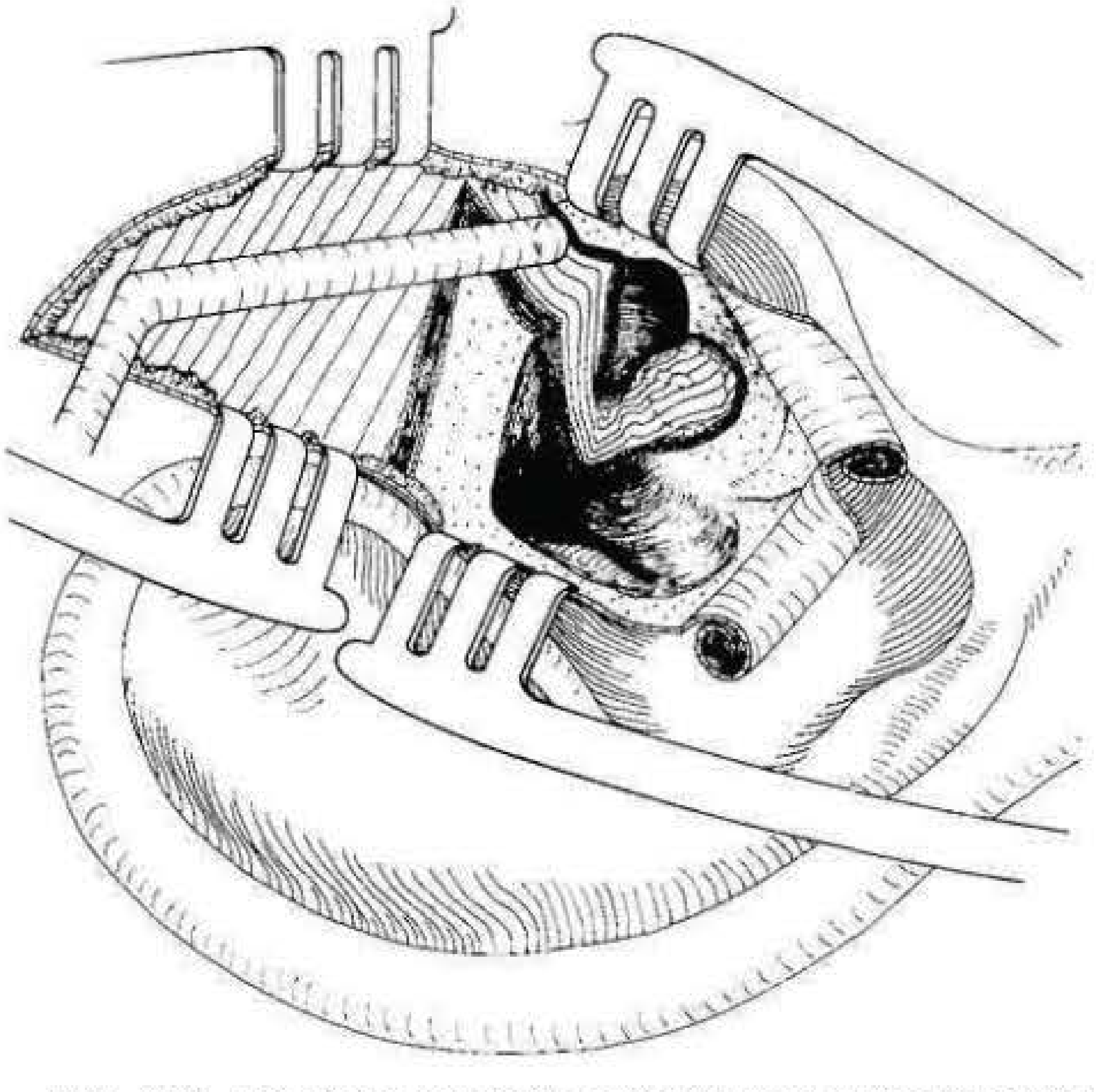


Fig. **869** The flap covers the anterior part of the mastoid tegmen, the aditus ad antrum, the attic, and the drum region

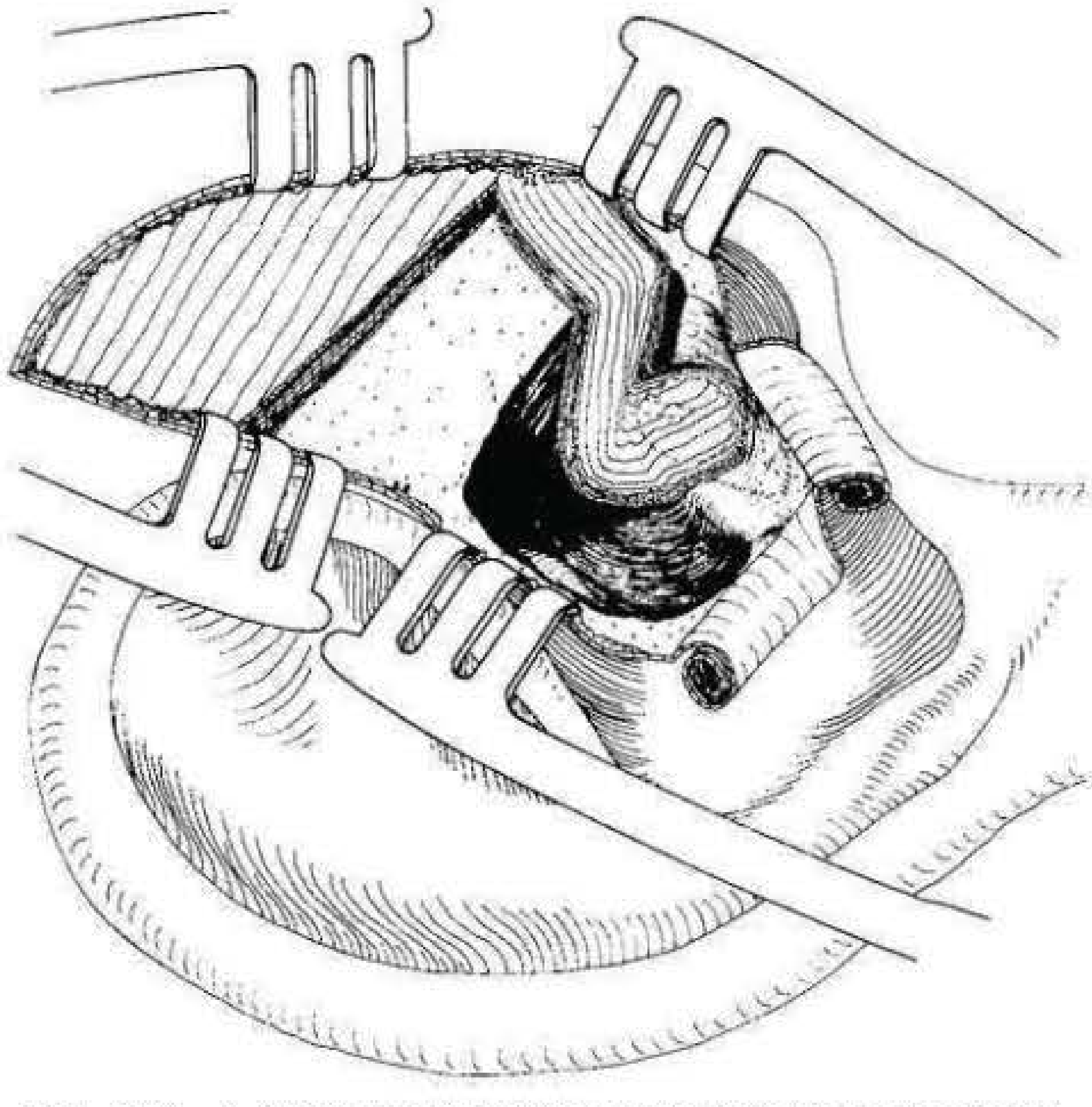


Fig. **870** A larger temporalis muscle flap is excised and placed in the antrum, aditus ad antrum, and attic, and onto the drum remnant

the malleus handle and elevated it laterally together with the annulus and ear canal skin (Rambo 1969). The Rambo method was often used in fenestration operations, and rapid healing of the cavity was often the case (Fritz and Crawford 1960).

Thorburn (1961), on the other hand, did not cover the tympanic cavity with the muscle flap, but used it to obliterate the cavity. In an endaural approach, after elevating a large, laterally-based ear canal skin flap and after a canal wall–down mas-

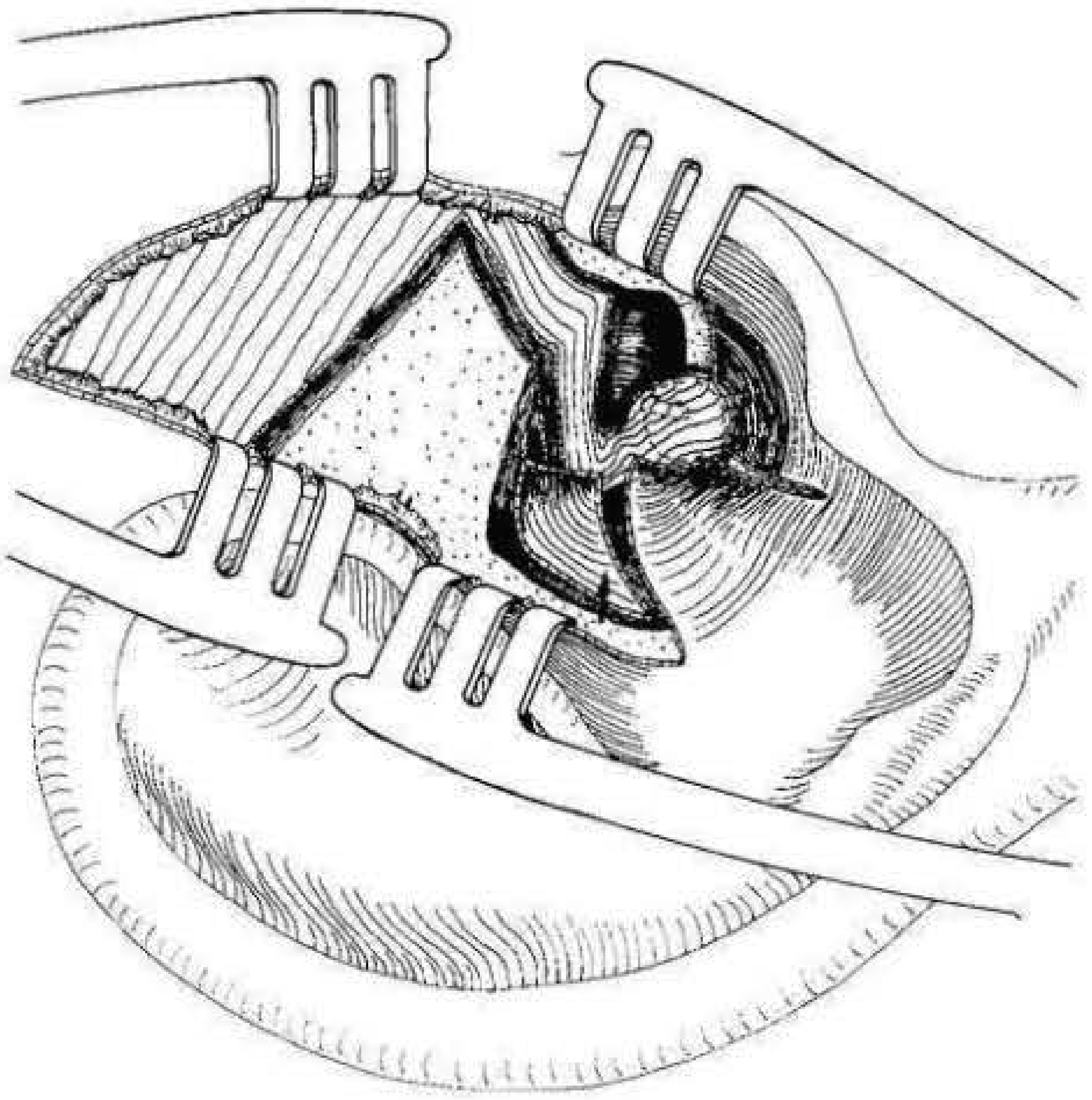


Fig. **871** The meatal skin flaps are replaced, as is the free ear canal skin flap covering part of the temporalis muscle and the cavity (arrow)

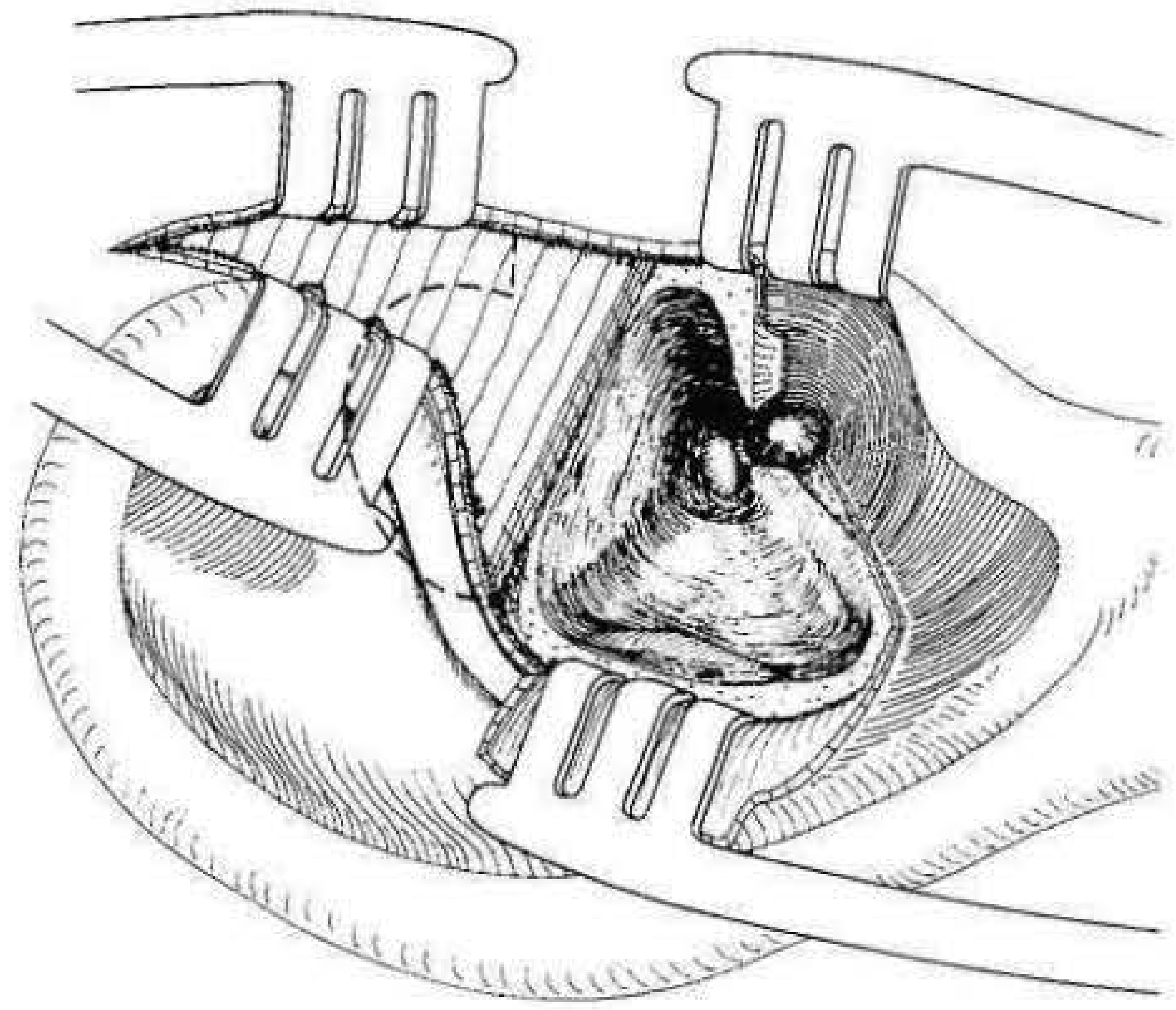


Fig. **872** **The Thorburn obliteration method.** An endaural approach, with a vertical incision extending to the top of the pinna and a canal wall–down mastoidectomy, is made. The ear canal skin is incised all the way around the annulus. There is no drum remnant, no malleus, and no stapes crura. The temporalis muscle fascia is exposed, and the size of the muscle flap is indicated by dashed lines

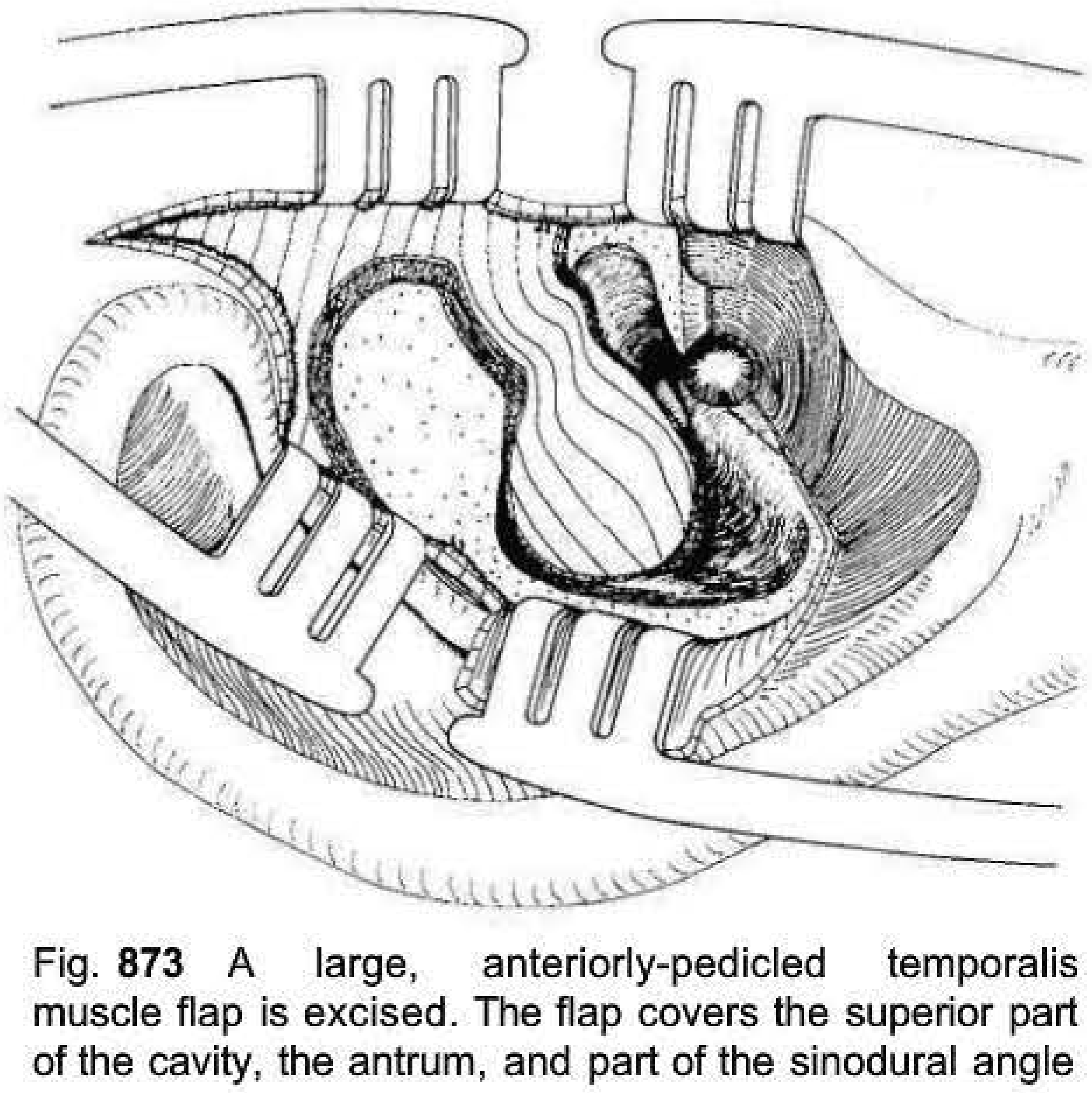


Fig. **873** A large, anteriorly-pedicled temporalis muscle flap is excised. The flap covers the superior part of the cavity, the antrum, and part of the sinodural angle

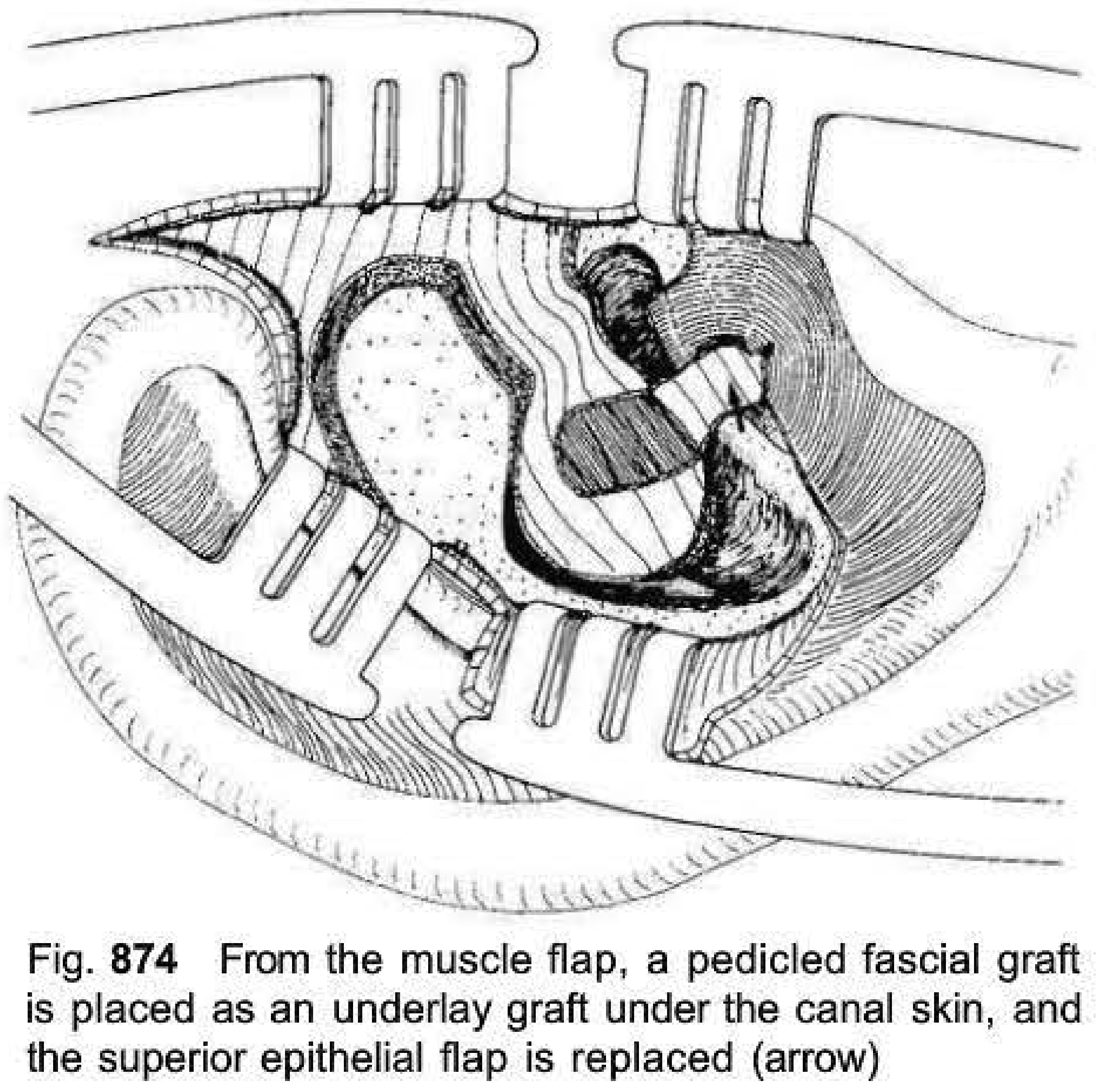


Fig. **874** From the muscle flap, a pedicled fascial graft is placed as an underlay graft under the canal skin, and the superior epithelial flap is replaced (arrow)

toidectomy, Thorburn elaborated an anteriorly-based temporalis muscle flap (Fig. **872**). The flap covers the superior part of the cavity (Fig. **873**). The tympanic cavity is covered with a fascial prolongation placed under the skin (Fig. **874**). The flaps are replaced, partly covering the muscle and partly covering the bone, and the ear canal is widened (Fig. **875**).

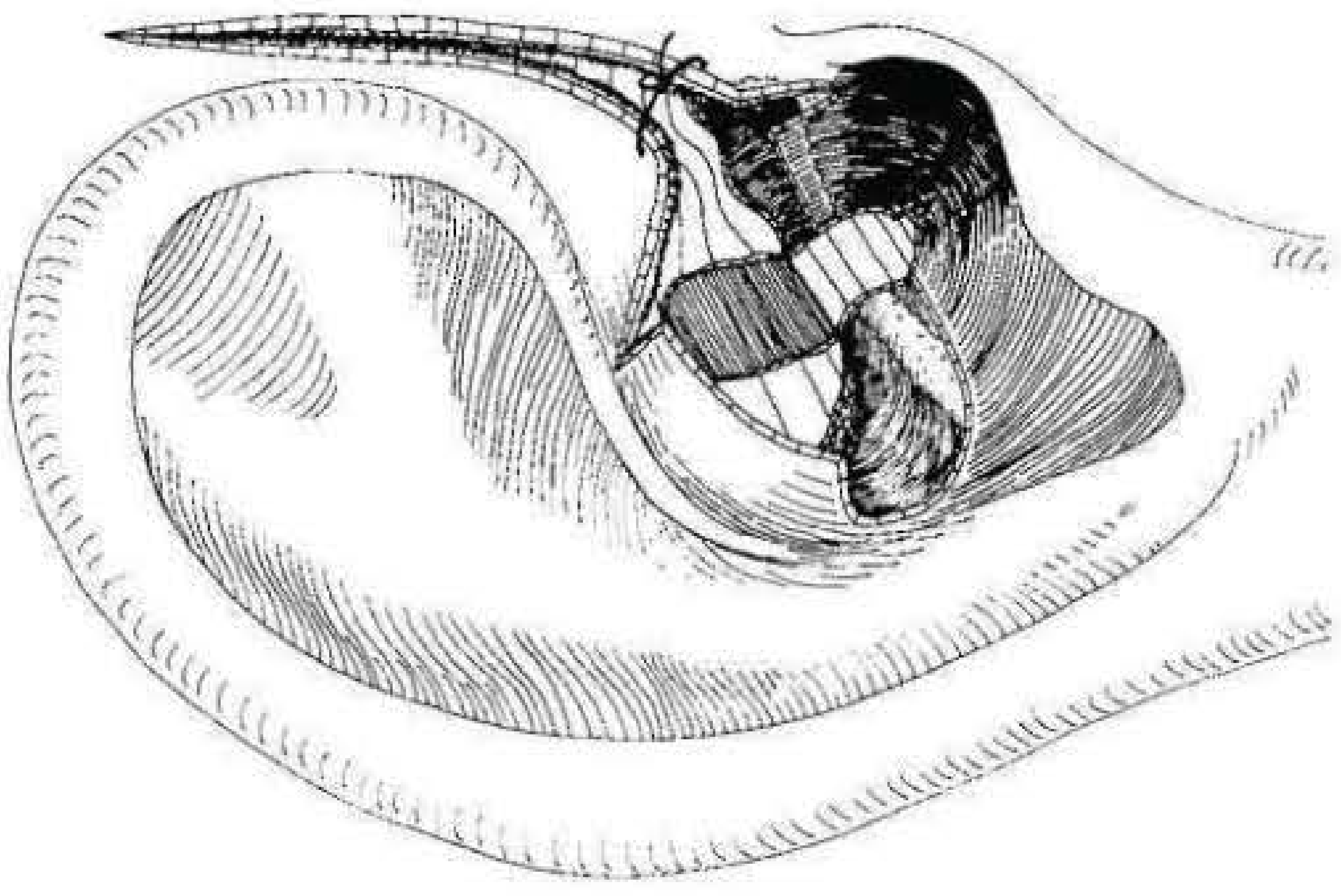


Fig. **875** The laterally-based skin flap is replaced, partly covering the muscle and partly the cavity wall. The skin incision will be sutured, maintaining a wide ear canal

The Freerichs and Williams Flap

Freerichs and Williams (1962) modified the Rambo technique in order to obliterate the mastoid cavity with temporalis muscle. After an endaural incision including a vertical extension 1 cm superior to the helix of the auricle, a laterally-based ear canal skin flap is elevated, exposing the posterior bony ear canal and the mastoid process (Fig. **876**). After posterior retraction of the auricle, the temporalis muscle fascia is exposed (Fig. **877**).

If only an atticotomy or a small atticoantrotomy is performed, a small muscle flap is used (Fig. **878**) to cover the bony defect (Fig. **879**). The perforation is closed with a free fascial graft, and the ear canal flap is returned.

If a canal wall–down mastoidectomy has been performed, then a large temporalis muscle flap with the fascia and the periosteum is elevated. The flap has a broad base anteriorly (Fig. **880**). It is placed in the cavity with a broad pedicle along the mastoid tegmen.

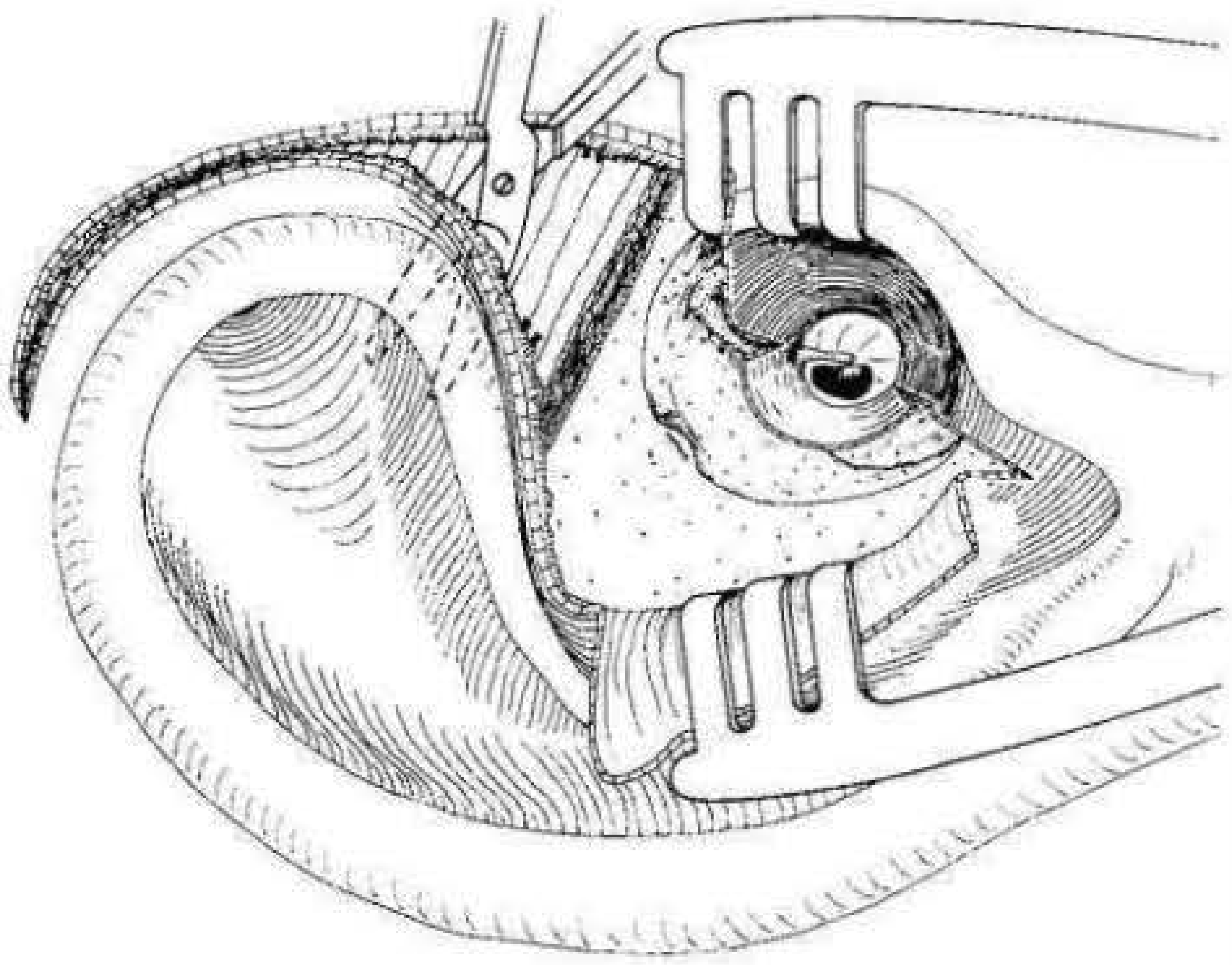


Fig. **876** **The Freerichs and Williams obliteration method.** An endaural approach is made, with a vertical incision extending 1 cm superior to the helix. The posterior ear canal skin is elevated laterally, making a laterally-based flap that is held aside by a selfretaining retractor The mastoid process is exposed. A medial radial incision at the 12-o'clock position, and a similar incision at the 5-o'clock position, are performed. With a pair of scissors, the auricle is elevated from the temporalis muscle fascia

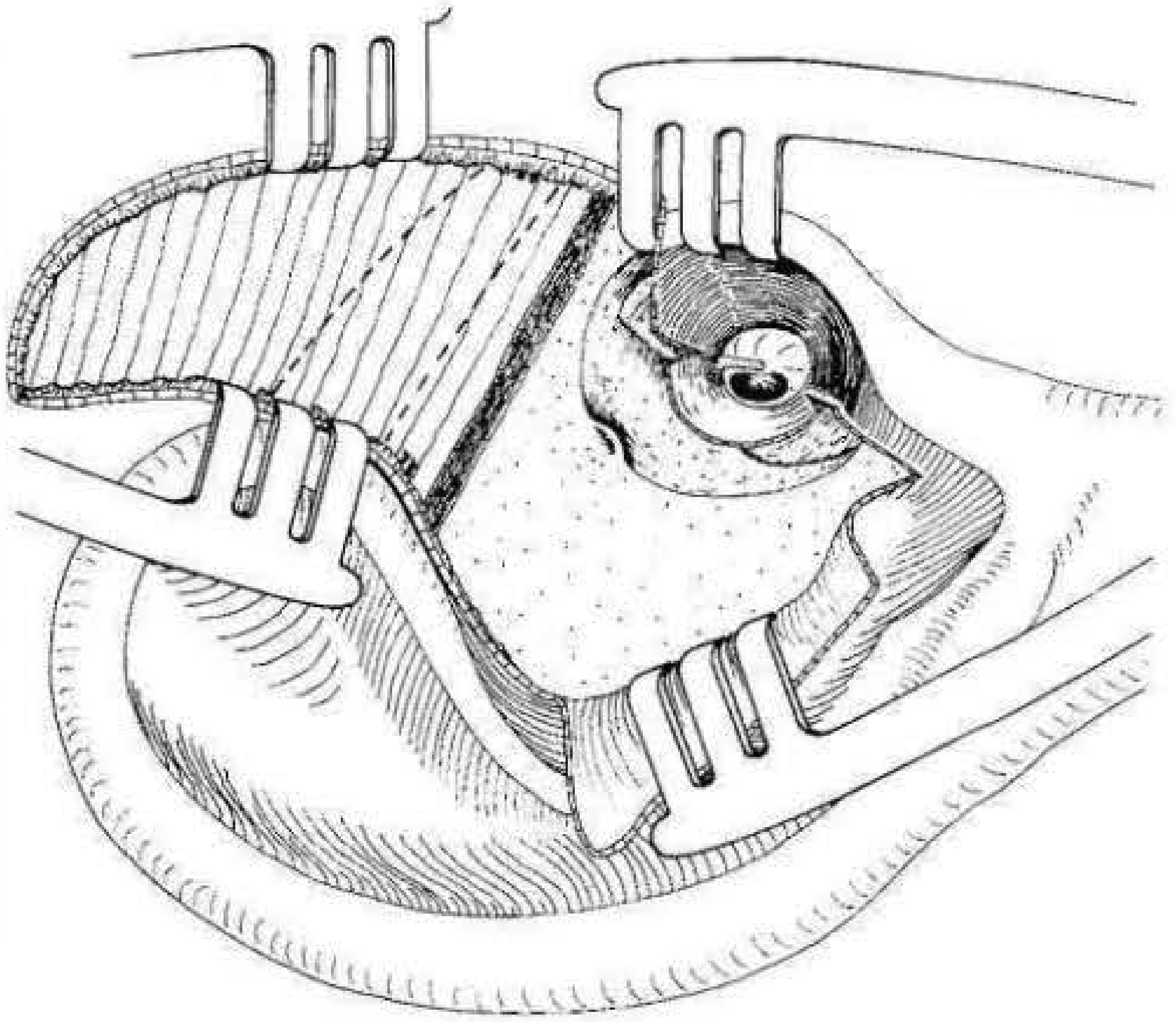


Fig. **877** The temporalis muscle fascia is exposed. A small and a large temporalis muscle flap are indicated by dashed lines

Using this type of flap, it is extremely difficult to reach the mastoid tip. Even the largest temporalis muscle flap will not reach (Fig. **881**).

Another problem of large, anteriorly based temporalis muscle flaps is that their pedicles may occupy too much space in the anterior part of the mastoid tegmen, and may contribute to narrowing of the ear canal.

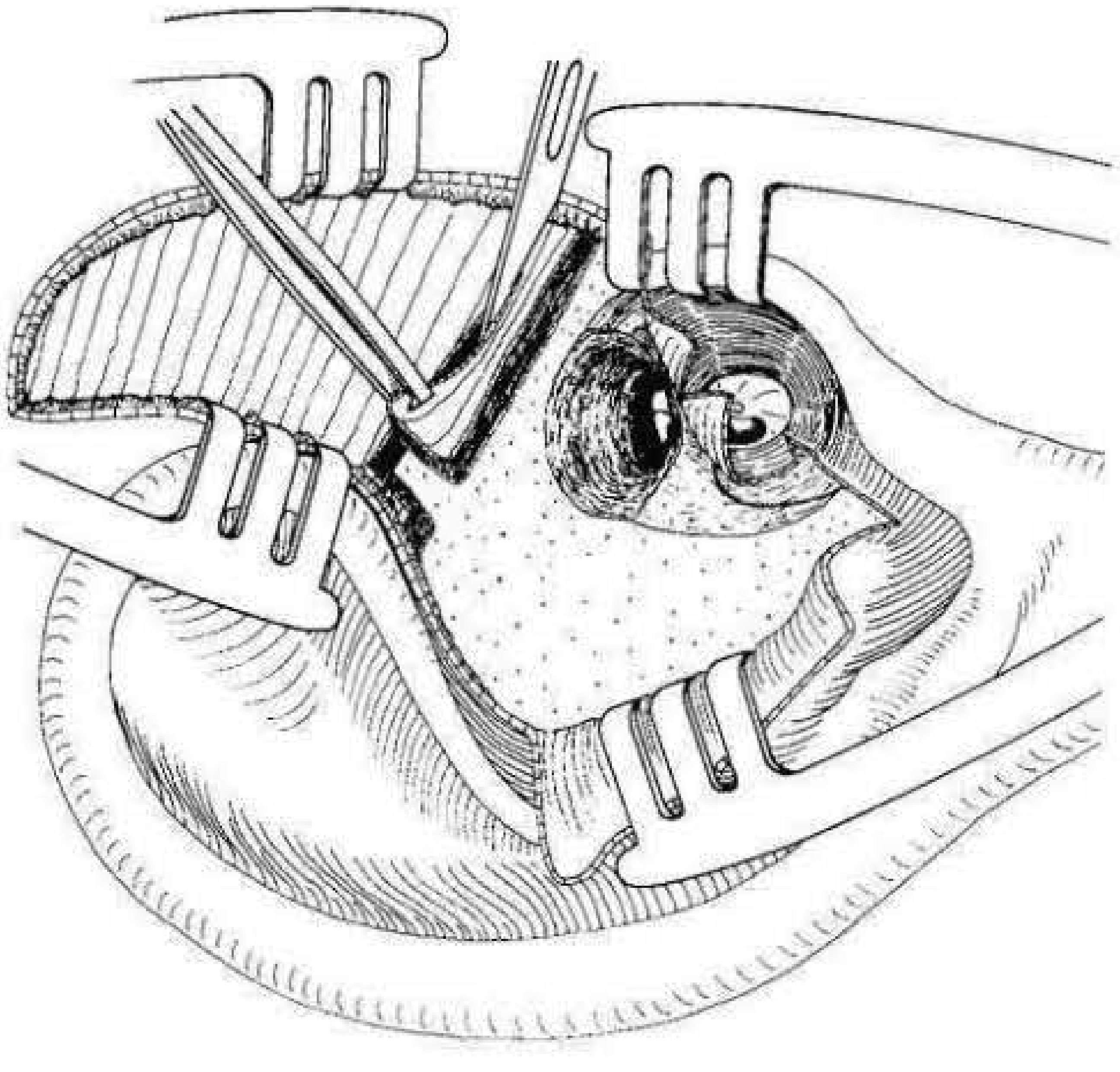


Fig. **878** An atticotomy is performed. A small, anteriorly-pedicled flap is cut from the inferior edge of the temporalis muscle

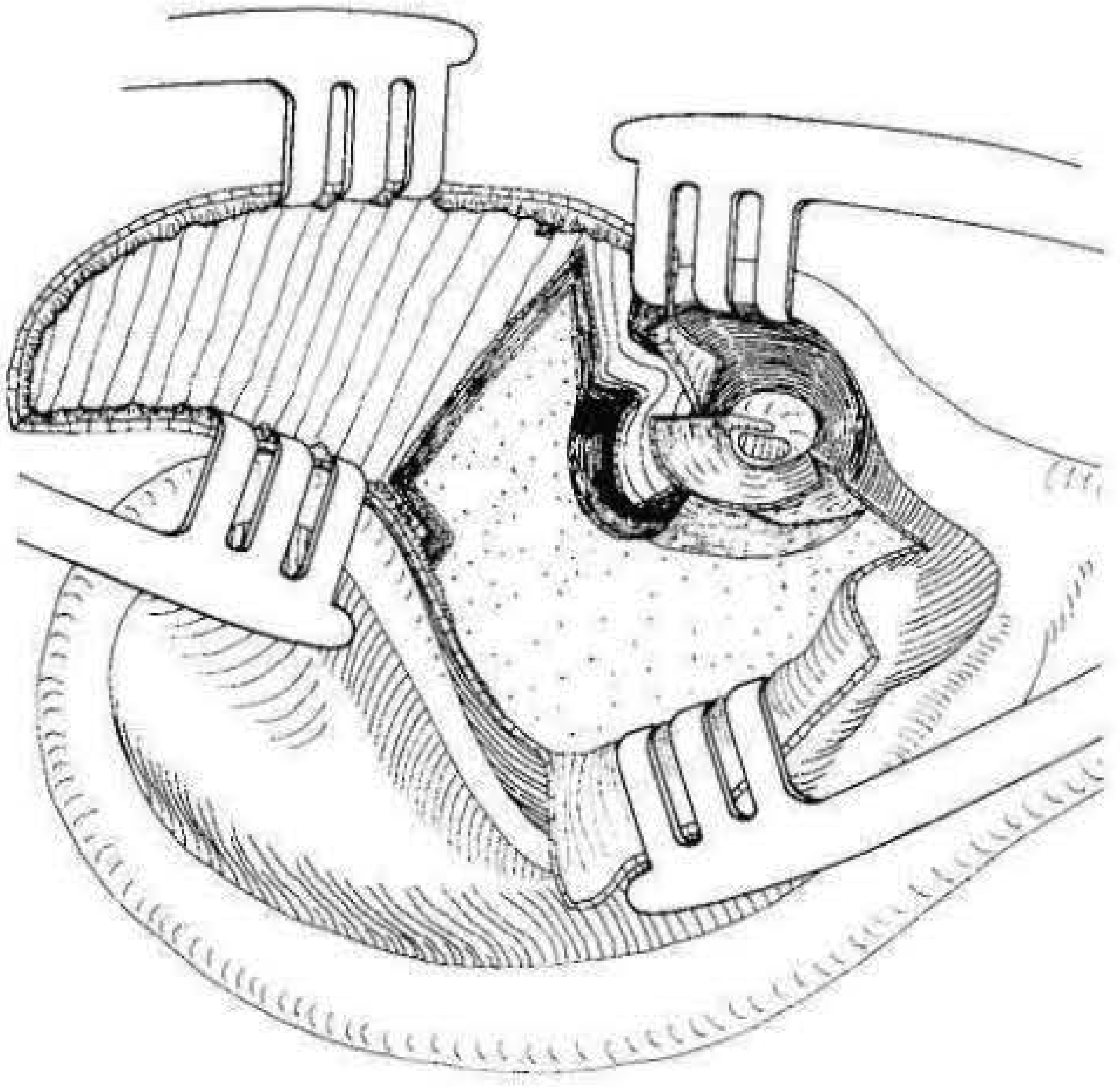


Fig. **879** The flap covers the atticotomy, and the tympanomeatal flap is replaced

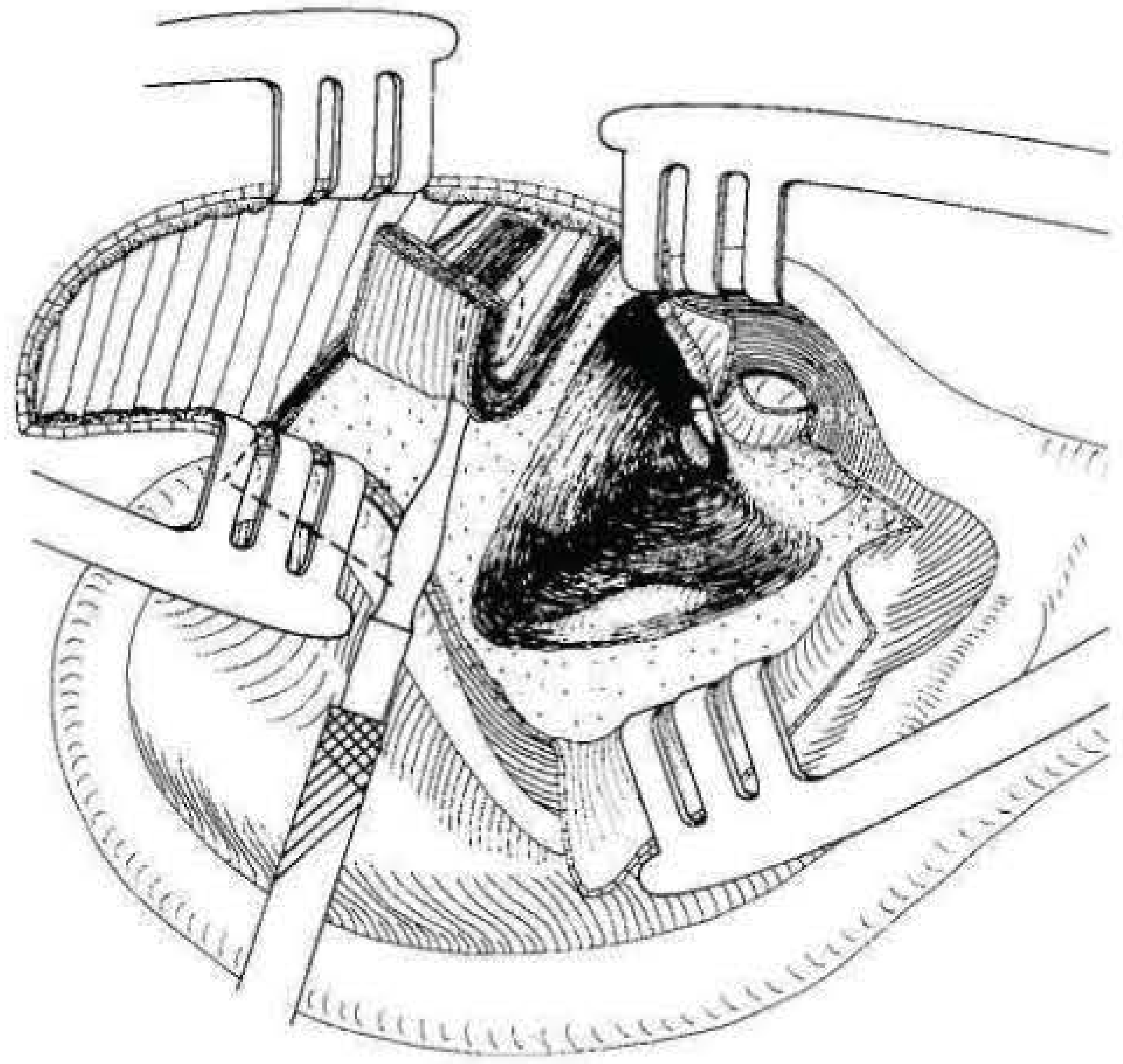


Fig. **880** A large, anteriorly-pedicled temporalis muscle flap is cut and elevated in a case of canal wall–down mastoidectomy with a preserved bridge, intact ossicular chain, and posterior perforation

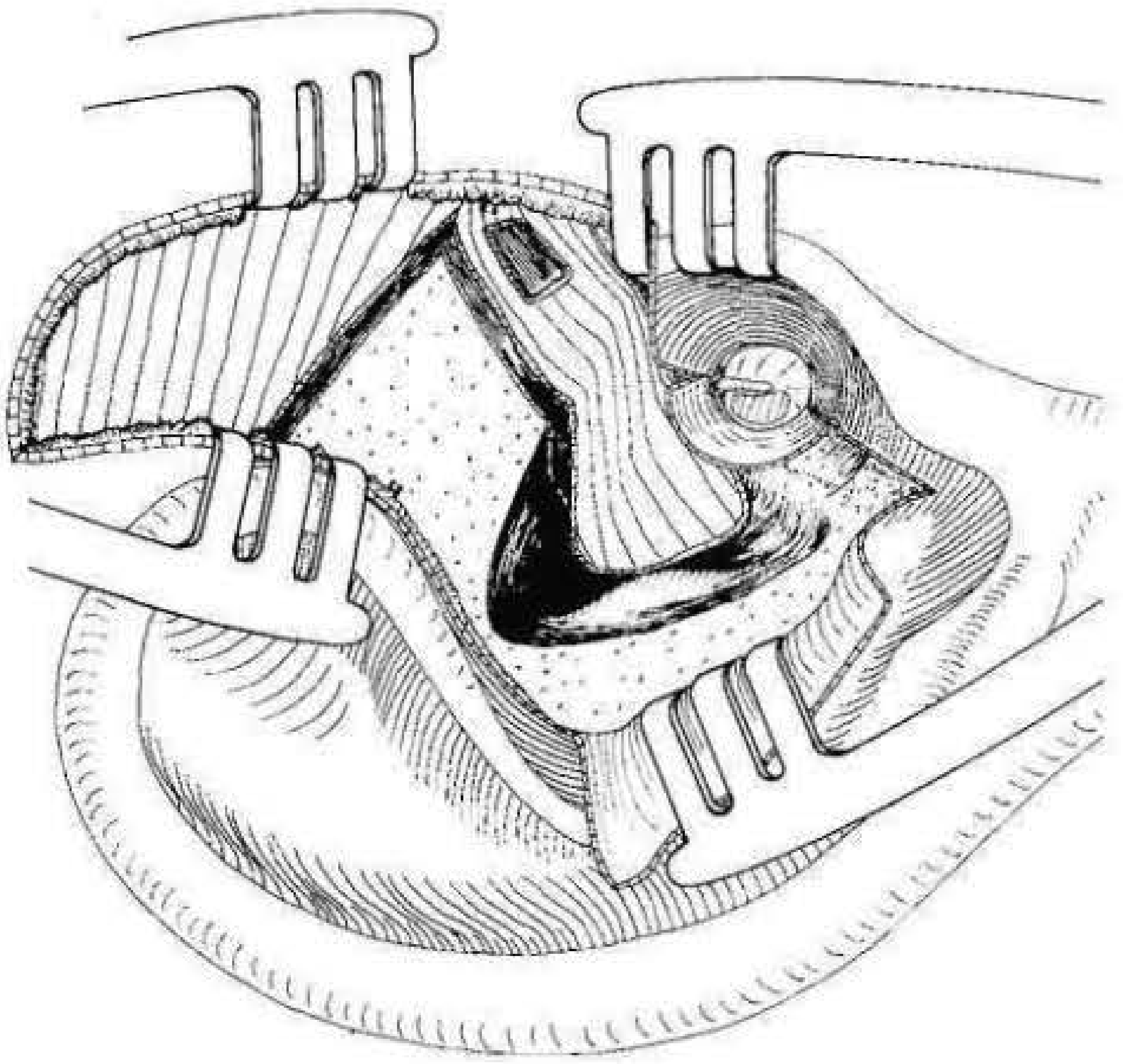


Fig. **881** The posterior perforation is closed with an underlay fascial graft taken from the temporalis muscle. A large, anteriorly-pedicled temporalis muscle flap covers the aditus ad antrum and the medial part of the cavity. The ear canal skin flaps are replaced

The Tos Bipartite Flap

Since 1962, the present author, when performing mastoid obliteration using temporalis muscle, and recognizing the difficulties of using the Rambo or Freerich flaps to reconstruct the ear canal wall or to cover both the antrum and the mastoid tip, has used a bipartite flap — one part obliterating the mastoid tip, and other the antrum (Tos 1969). The flap includes retroauricular tissue and the temporalis muscle.

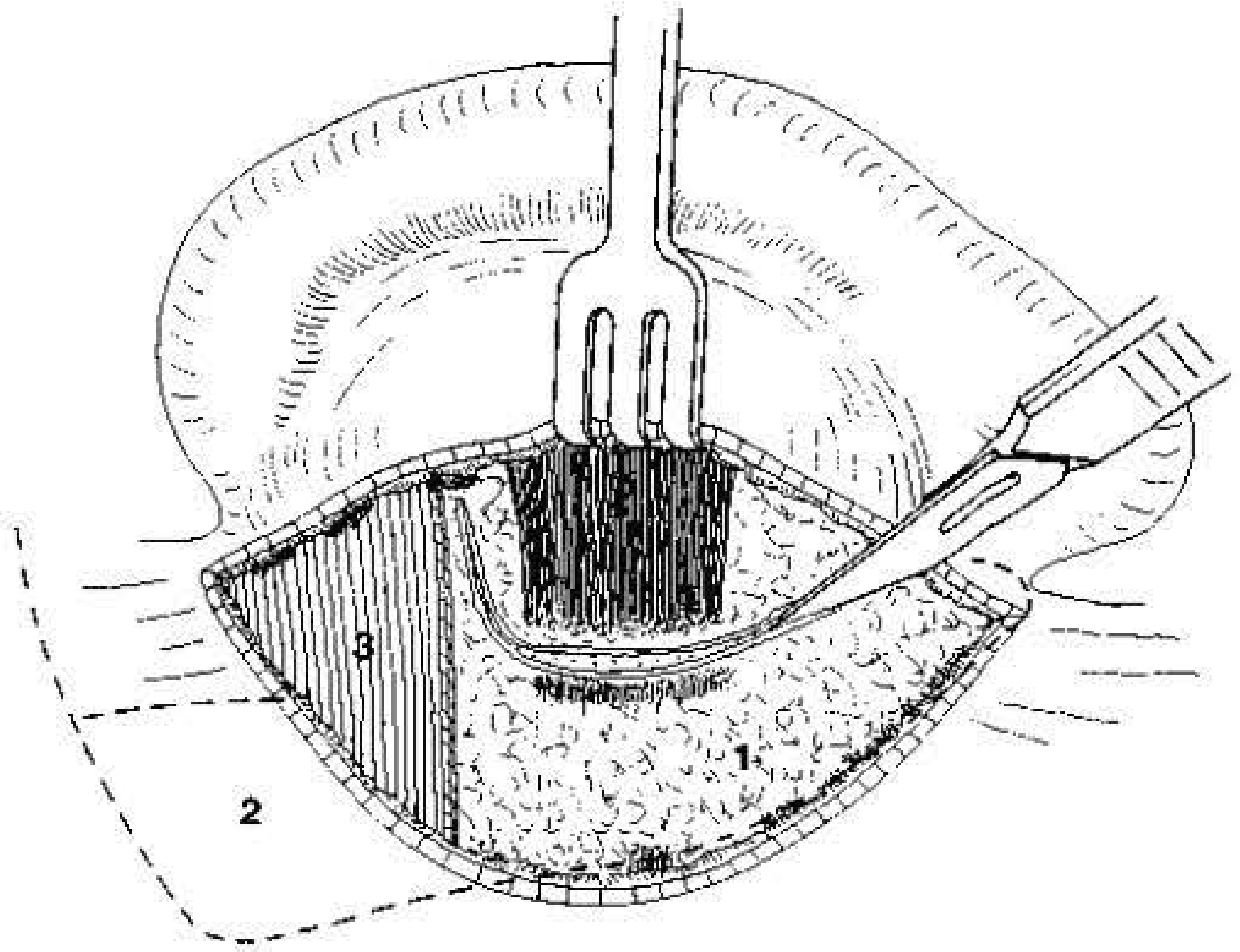


Fig. **882** **The Tos obliteration method with a bipartite flap.** After a retroauricular skin incision 1 cm behind the retroauricular fold, the skin is elevated. An incision through the subcutis–periosteum tissue and the posterior auricular muscle runs along the entrance of the ear canal and extends toward the mastoid tip. The size of the bipartite flap is indicated by dashed lines. (1) the inferior flap, (2) the posterior flap, (3) the base of the flap

A retroauricular skin incision is made 1 cm behind the retroauricular fold. The skin is elevated, and a curved incision is made through the subcutis, the posterior auricular muscle, and the periosteum, running along the entrance of the ear canal and extending toward the mastoid tip (Fig. **882**). The fibrous tissue and periosteum are elevated and retracted posteriorly. This tissue will be included in the flap (Fig. **883**). After the canal wall–down mastoidectomy (Fig. **884**), dissection of the musculoperiosteal flap is started at the mastoid tip, including as much muscle as possible. If necessary, the attachment of the sternocleidoid muscle — but always parts of the splenius capitis muscle, transversus nuchae muscle, and longissimus capitis muscle — is included in the inferior part of the flap, which is thicker than the upper part (Fig. **885**). The flap is cut and elevated in a superior direction. The retractor has to be repositioned and the skin retracted maximally in order to elevate and dissect the upper part of the flap (Fig. **886**). Using a pair of scissors, the flap is cut posteriorly (Fig. **887**) and as far as possible superiorly and anteriorly (Fig. **888**). Finally, the base of the flap is placed in the cavity in such a way that it forms a firm "wall" in the region of the removed posterior bony ear canal wall. The inferior end of the flap is placed in the mastoid tip. In the posterosuperior part of the flap, a vertical incision is made, thus creating the posterior part of the flap (Fig. **889**). This

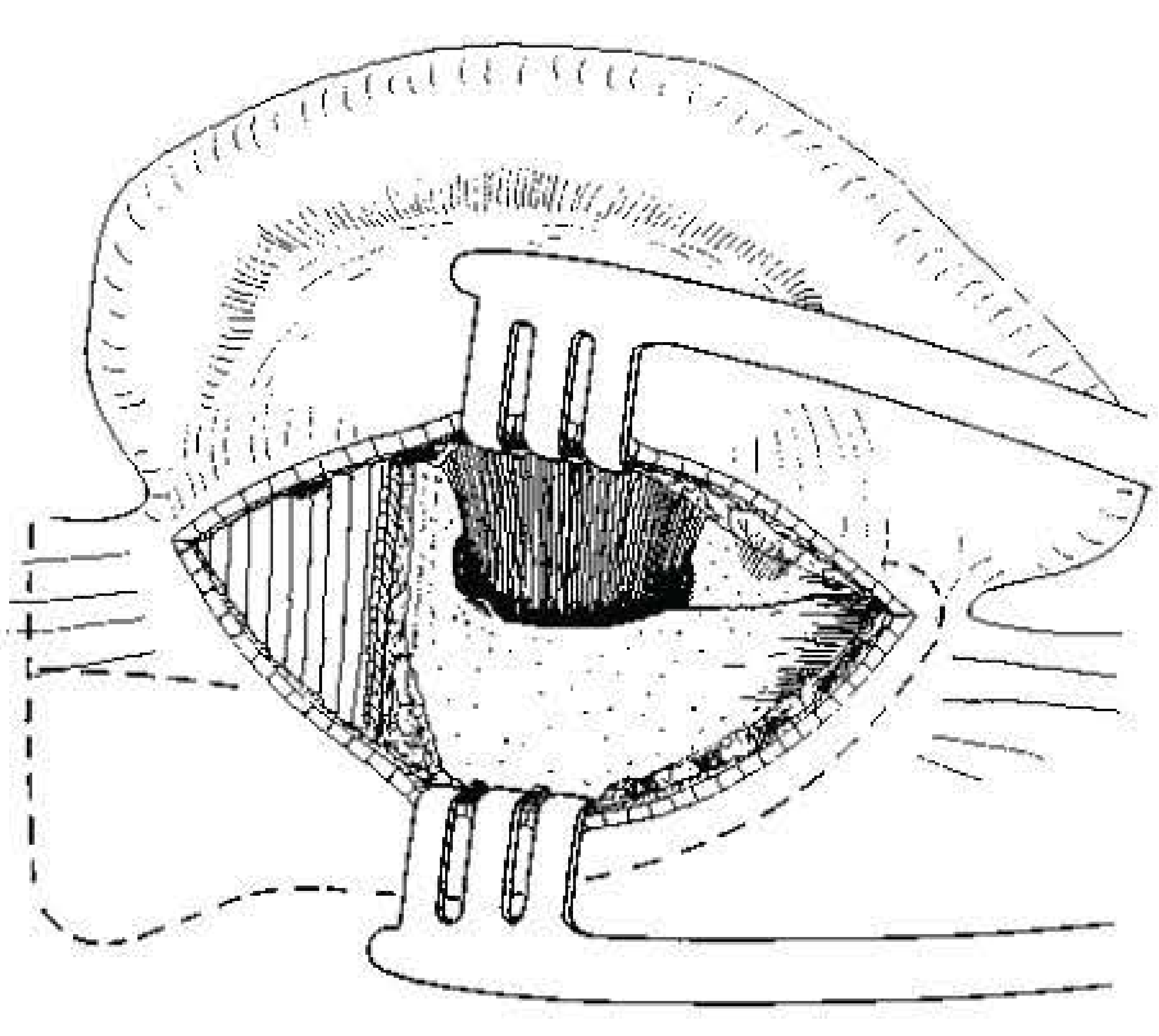


Fig. **883** The retroauricular tissue is elevated with the periosteum and retracted posteriorly, exposing the mastoid plane and the entrance of the ear canal

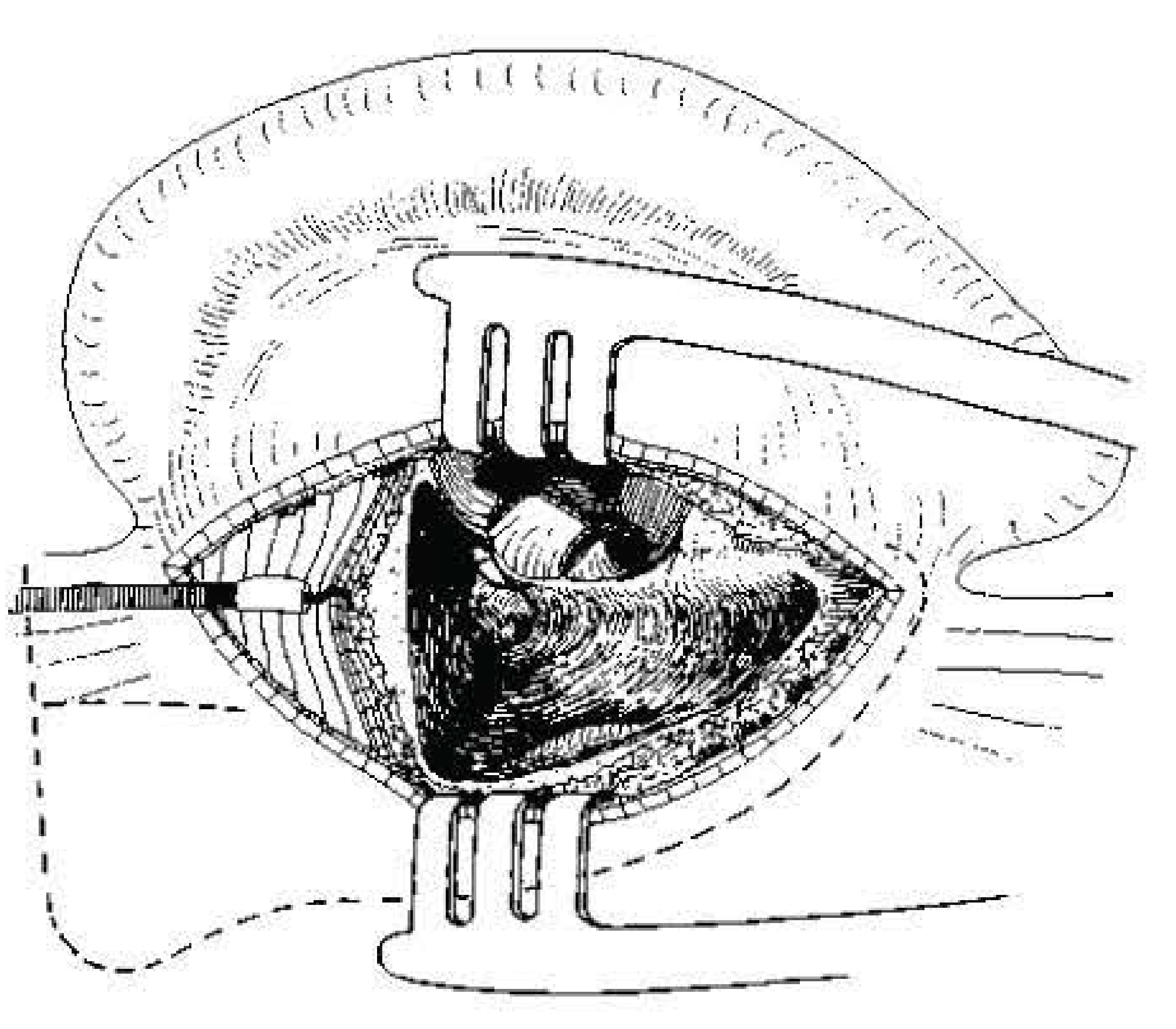


Fig. **884** The ear canal skin flaps are elevated. A canal wall–down mastoidectomy with preserved bridge is performed

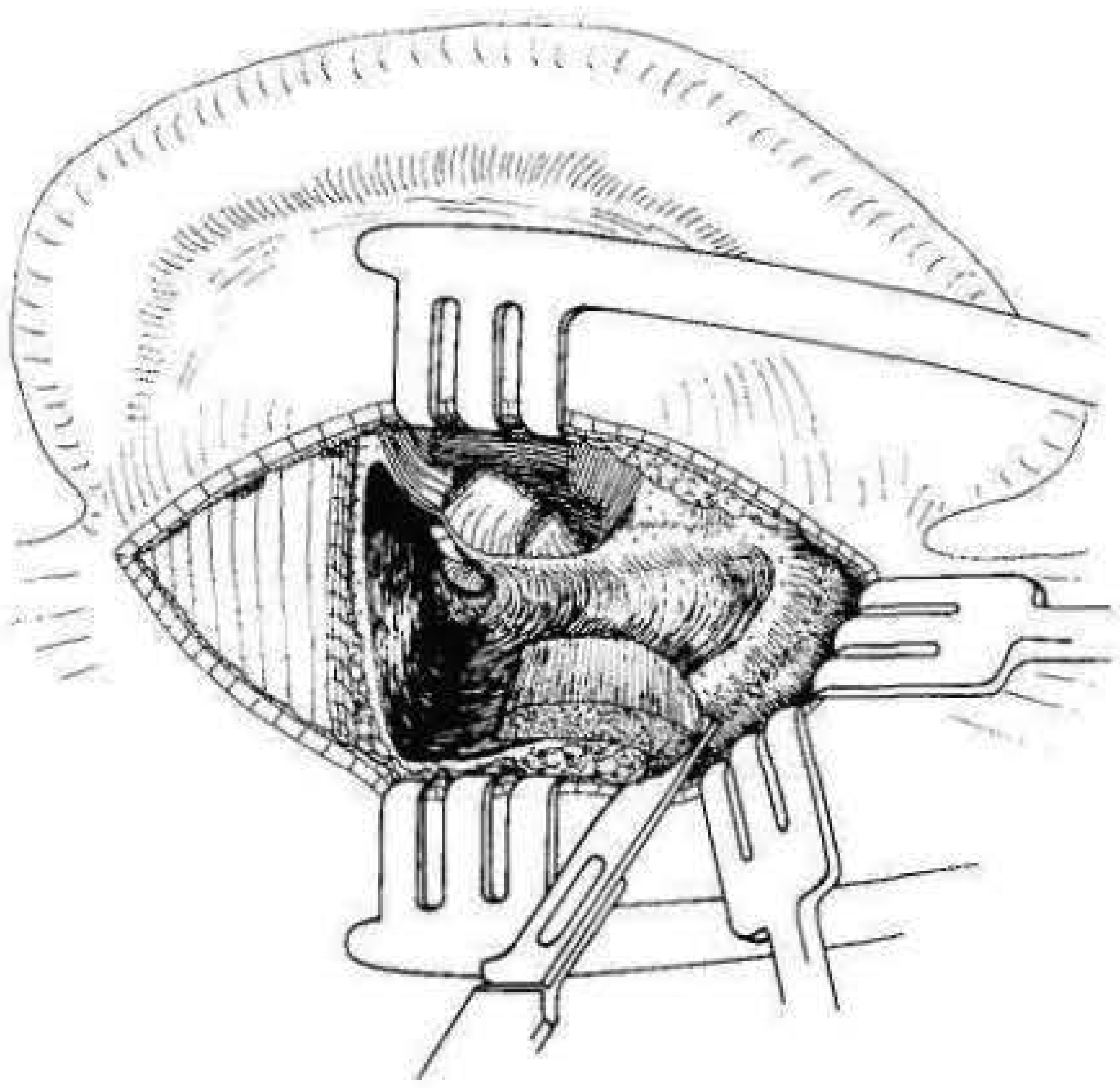


Fig. **885** Dissection of the muscle flap is started inferiorly, beyond the mastoid tip. After further retraction of the skin, the fibers of the sternocleidomastoid muscle, the splenius capitis muscle, and the transversus nuchae muscle attached to the posterior aspect of the mastoid tip are cut with a knife

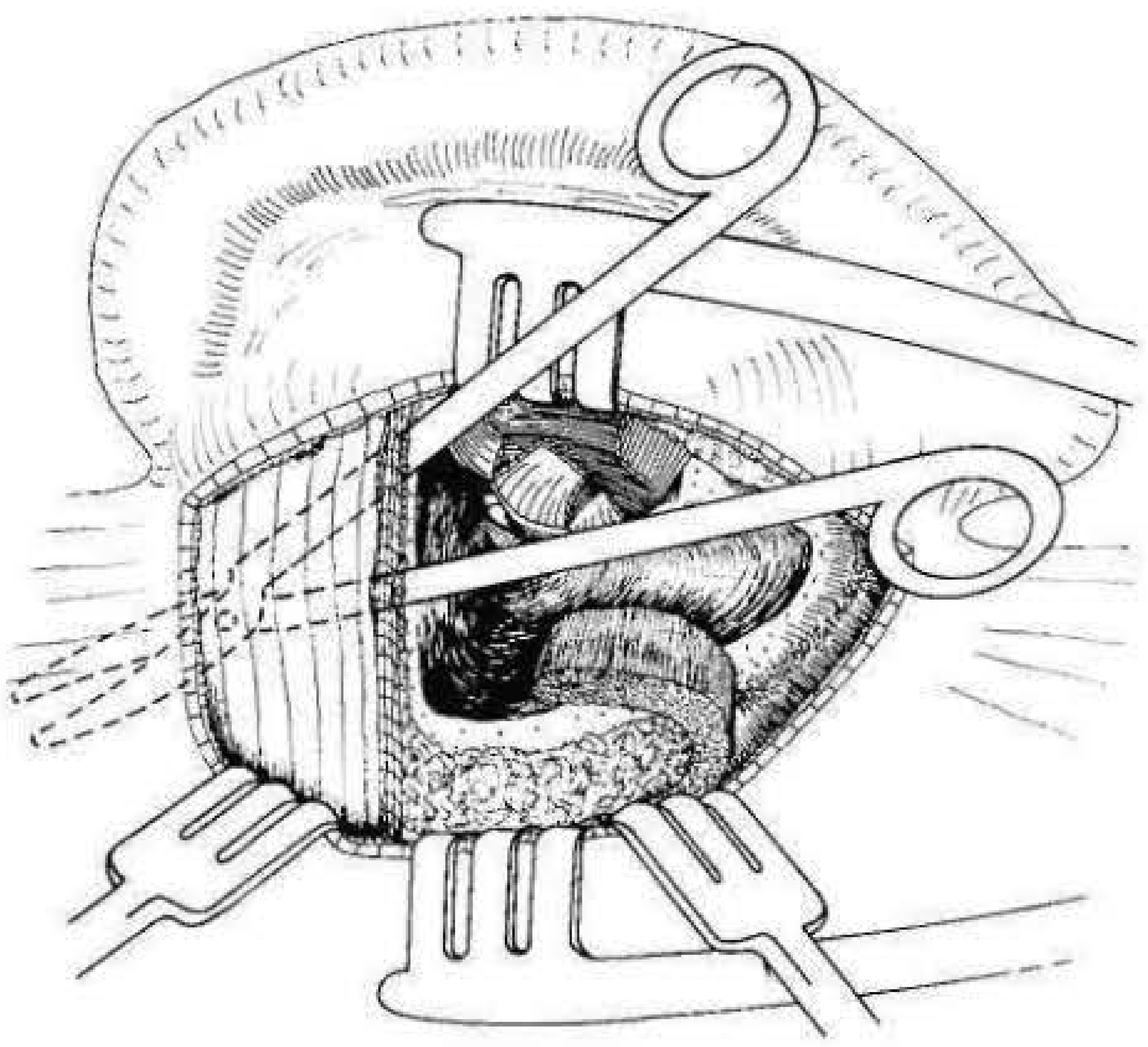


Fig. **886** After further retraction of the skin posteriorly, the fibrous tissue posterior to the cavity is exposed and, together with the temporalis muscle, detached from the bone

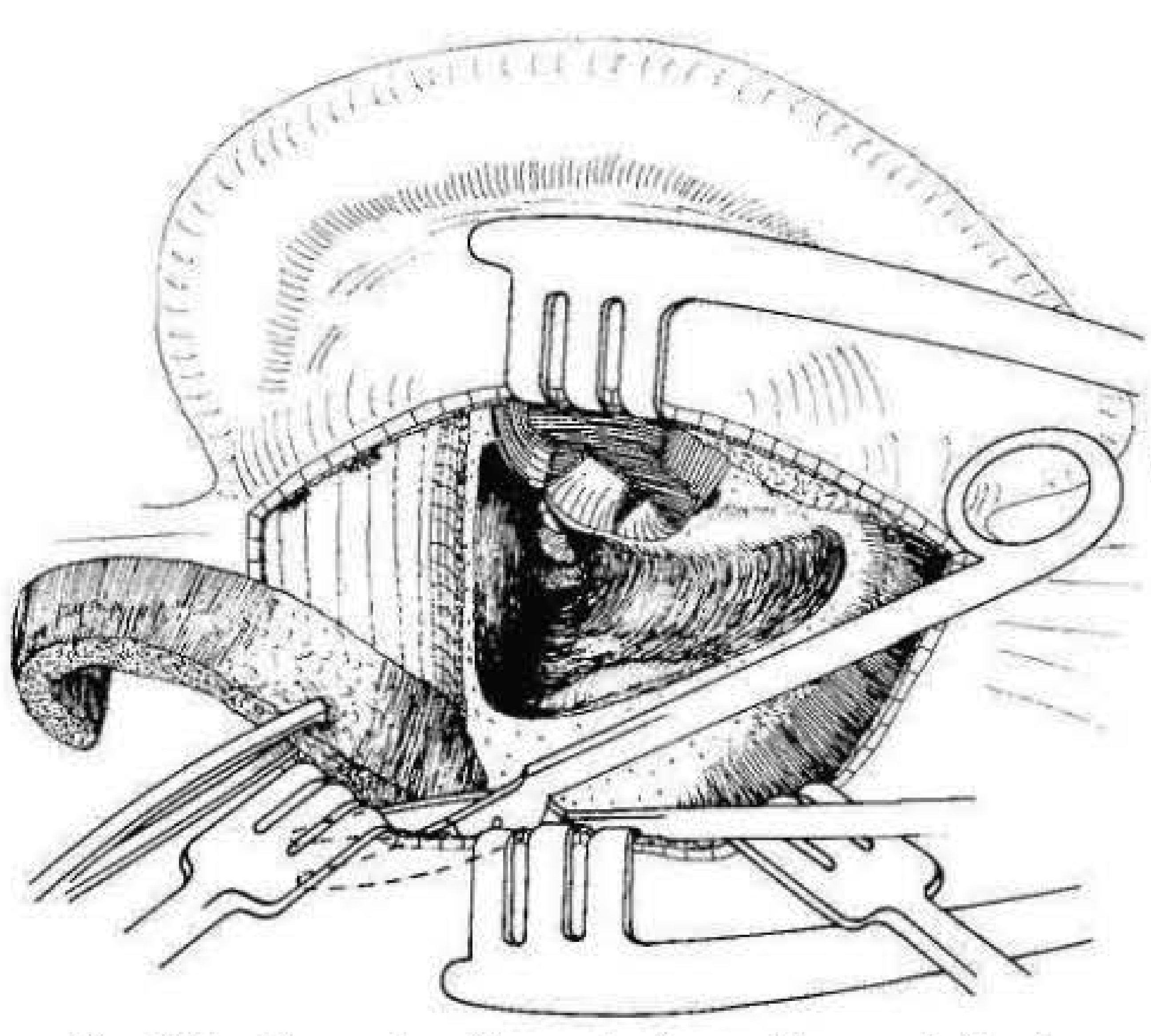


Fig. **887** The subcutis–periosteum flap and the temporalis muscle are cut posteriorly with a pair of scissors after maximal retraction of the skin

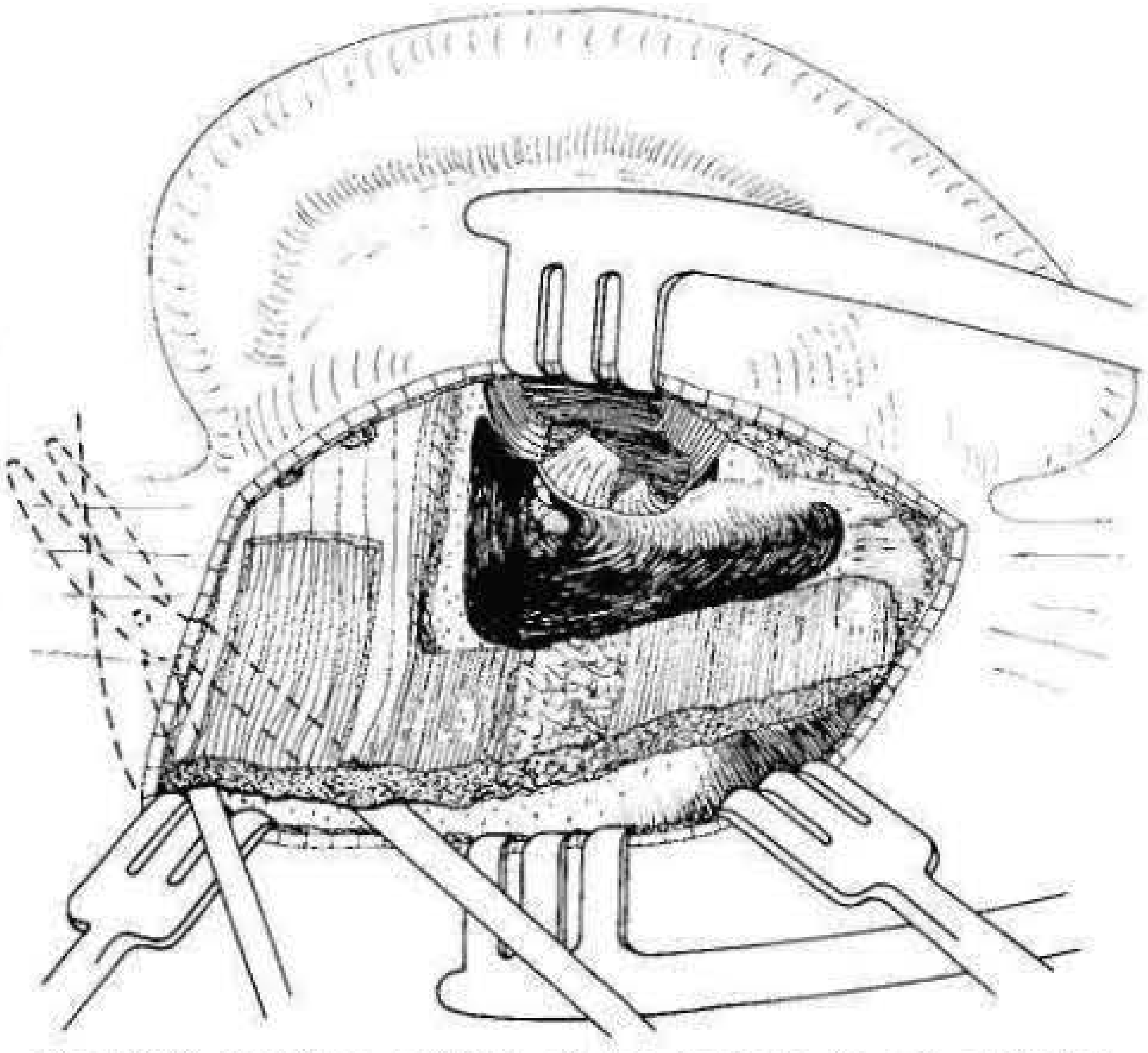


Fig. **888** Further cutting of the muscle in an anterior direction along the horizontal dashed line is partly performed blindly. A large flap is now mobilized. A large piece of temporalis muscle fascia is harvested, and the muscle flap can be cut along the vertical line

flap is turned down into the antrum and sinodural angle (Fig. **890**).

Before the muscle flap is placed, a piece of fascia is harvested from the temporalis muscle (Fig. **888**). The fascia closes the ear drum perforation and covers the posterior ear canal skin, separating the skin from the muscle (Fig. **889**). The canal skin flaps are returned, allowing rapid epithelialization of the enlarged ear canal over the fascia. The cavity is firmly obliterated, since the flaps are not under tension and are reasonably vascularized (Fig. **890**).

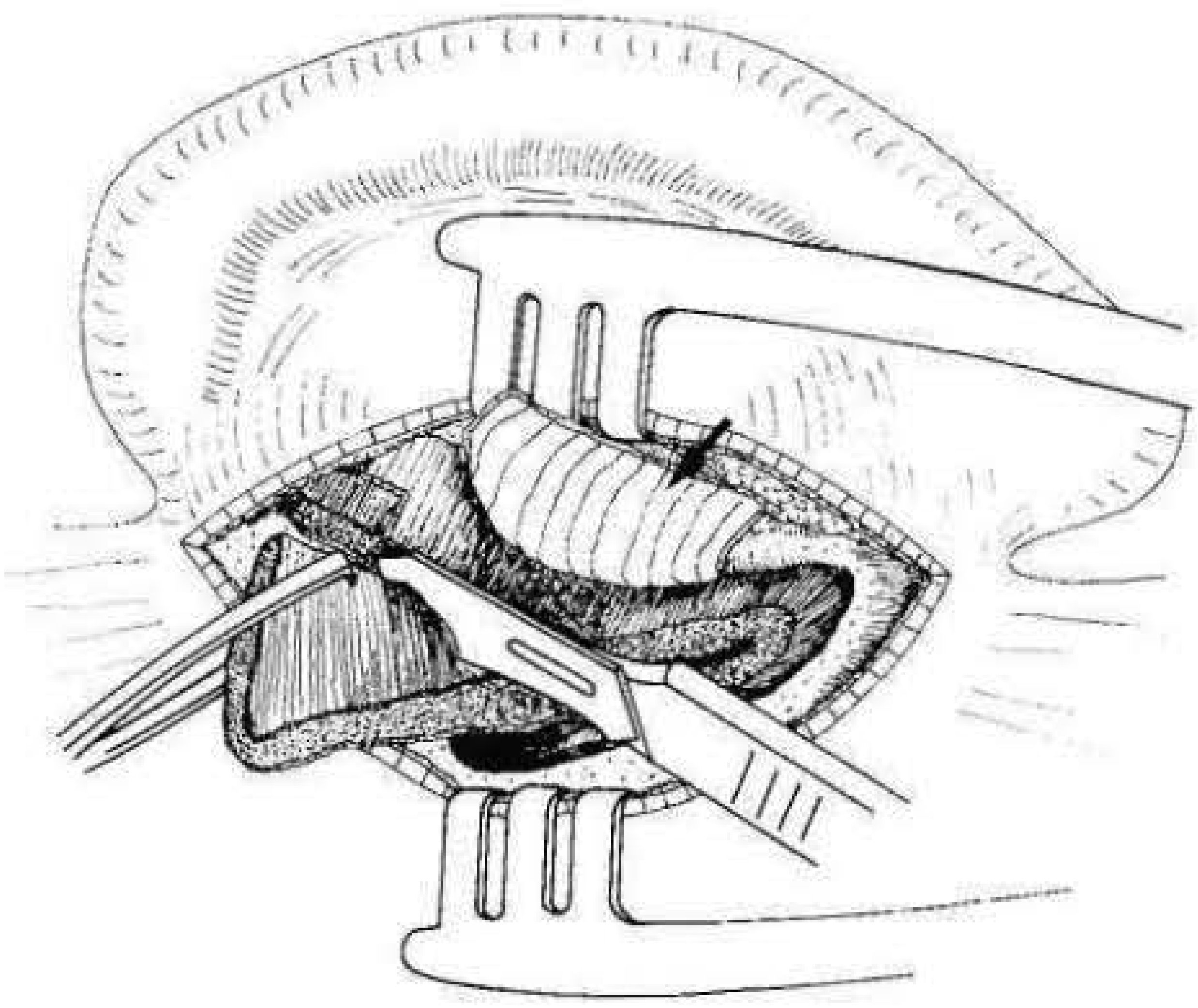


Fig. **889** The fascial graft is placed in the tympanic cavity. After the ear canal skin flaps have been replaced, the temporalis muscle fascia covers the posterior aspect of the ear canal (arrow). The inferior part of the subcutis–muscle flap fills the mastoid tip, and the middle part forms the ear canal. In the posterosuperior part of the temporalis muscle, a vertical incision is completed, making a posterior flap obliterating the antrum and sinodural angle

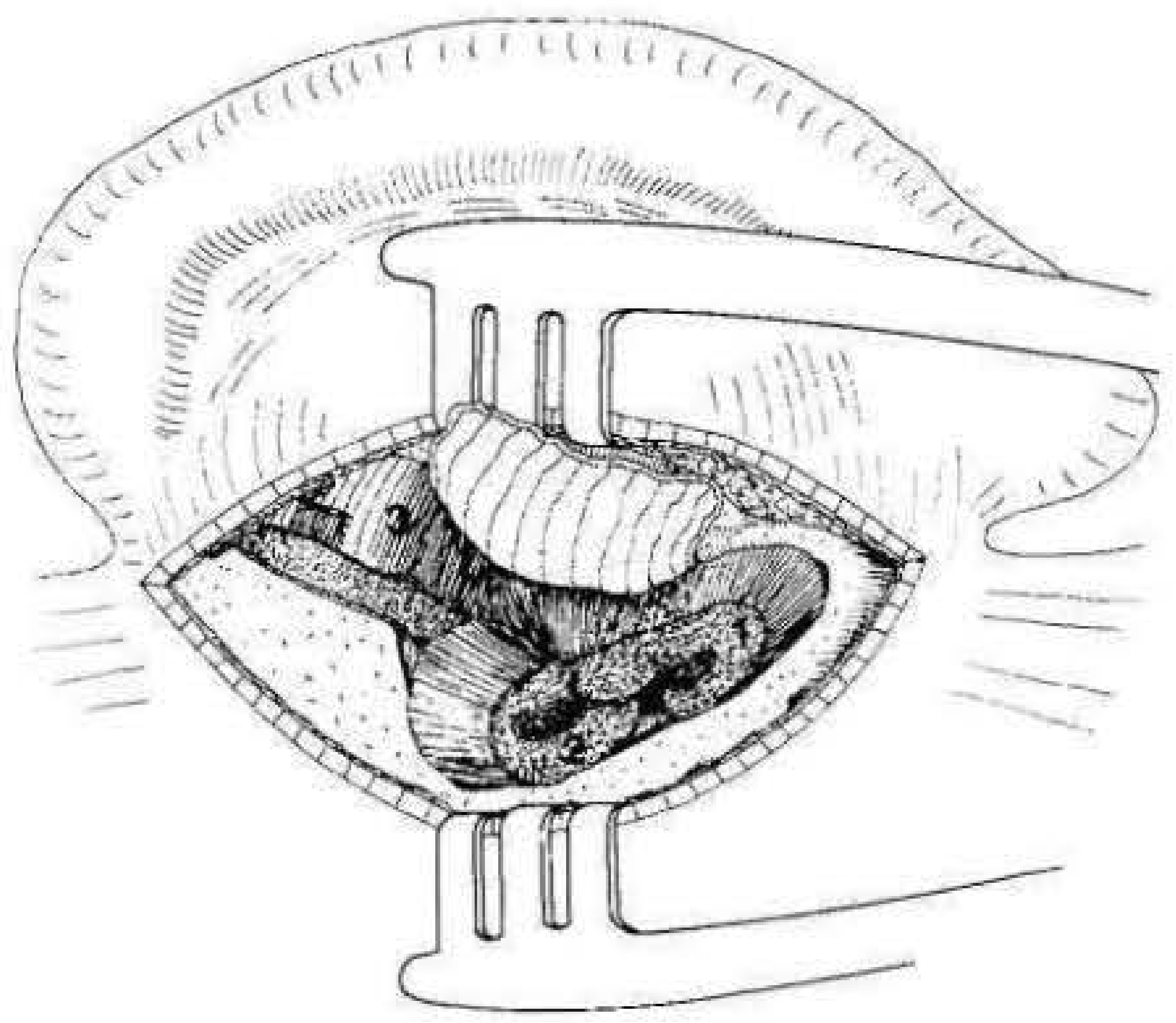


Fig. **890** The bipartite flap is now in place. One end fills the inferior part of the cavity (1), and the other the antrum and the sinodural angle (2). The base of the flap (3) covers the superior wall of the cavity and forms the ear canal wall, behind the temporalis fascia graft

If the fascia is not large enough to cover the ear canal, a small, anteriorly-based pedicled Palva flap can be made from the anterior subcutis periosteum flap, including the postauricular muscle (Fig. **882**) attached to the posterior aspect of the conchal eminence. The flap is pulled posteriorly to cover the fascia (Figs. **891** and **892**).

Before obliteration, the ear canal is widened with incisions at the 12-o'clock and 6-o'clock positions running through the external auditory meatus. The ear canal is packed with Gelfoam balls immediately after the fascia is placed and after, the canal skin flaps have been replaced. Finally, a 1-cm strip of gauze moistened with oxytetracycline and hydrocortisone ointment (Terra-Cortril) is placed in the widened ear canal (Fig. **892**). The pack is removed after three weeks. A further piece of gauze is placed in the ear canal for at least a further two weeks in order to keep it widened.

The late results one to six years after surgery on 103 patients were good (Tos 1969). Eighty percent remained completely dry with no postoperative aural complaints, and 11% had intermittent discharge during the first six to 12 months postoperatively, but thereafter it ceased and at further follow-up checks, the ears were dry and the cavity was epithelialized. The majority of patients developed some residual cavity, but the cavity lining was intact and the migration properties of the epithelium were good, with the cavities generally being selfcleaning.

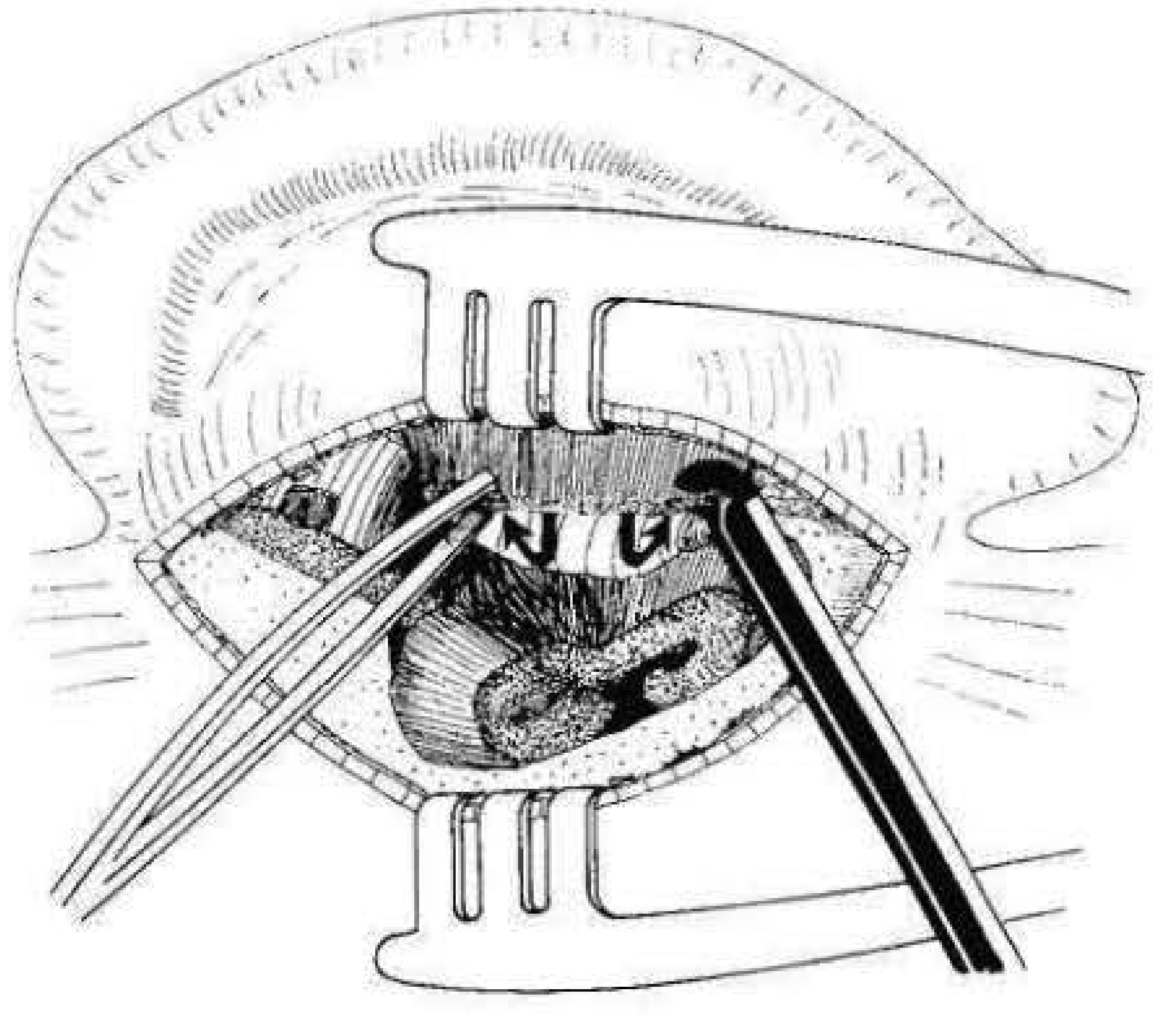


Fig. **891** From the fibrous tissue and the remnant of the postauricular muscle, a small anterior pedicled flap is elaborated and pulled behind the fascia (arrows)

This method allows obliteration of large cavities, because a large part of the temporalis muscle, as well as the retroauricular fibrous tissue and the mastoid tip muscles, are included in the flap. The retroauricular incision is, however, essential for this flap.

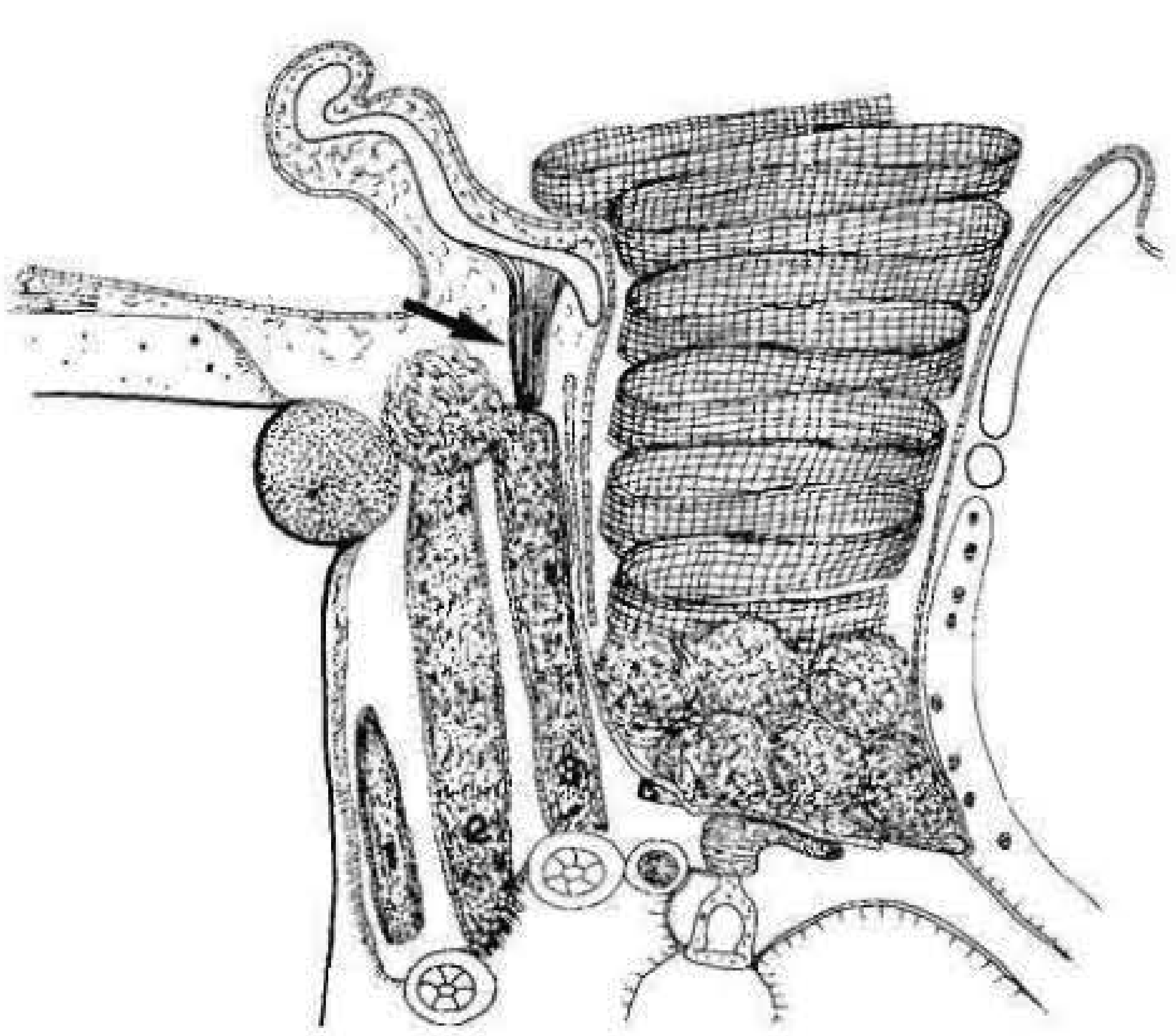


Fig. **892** **The Tos bipartite flap, seen in a side view.** A large piece of fascia covers the ear drum perforation as an underlay graft. It is attached to the preserved bridge, and continues laterally under the laterally-based canal skin graft, forming the ear canal. The relatively solid muscle flaps are obliterating the cavity, the inferior part (1), the posterior part (2), and the anterior part (3), forming the ear canal wall. From the concha, a small pedicled flap, consisting mainly of postauricular muscle, covers the fascia (arrow). The ear canal is widened and packed with Gelfoam balls and a gauze moistened with oxytetracycline and hydrocortisone (Terra-Cortril) ointment

The Guilford Superior Pedicled Flap

The Guilford (1961) flap is used in an endaural approach and the flap is harvested using a retroauricular incision (Fig. **893**). The base is located anterosuperiorly at the junction of the temporalis muscle with the postauricular muscle. The flap contains the subcutaneous and fibrous tissue, the postauricular muscle, and the periosteum. After a retroauricular incision, the subcutis muscle flap is elevated (Fig. **894**). The flap covers the mastoid tegmen, the sinodural angle, and the medial wall of the cavity (Fig. **895**).

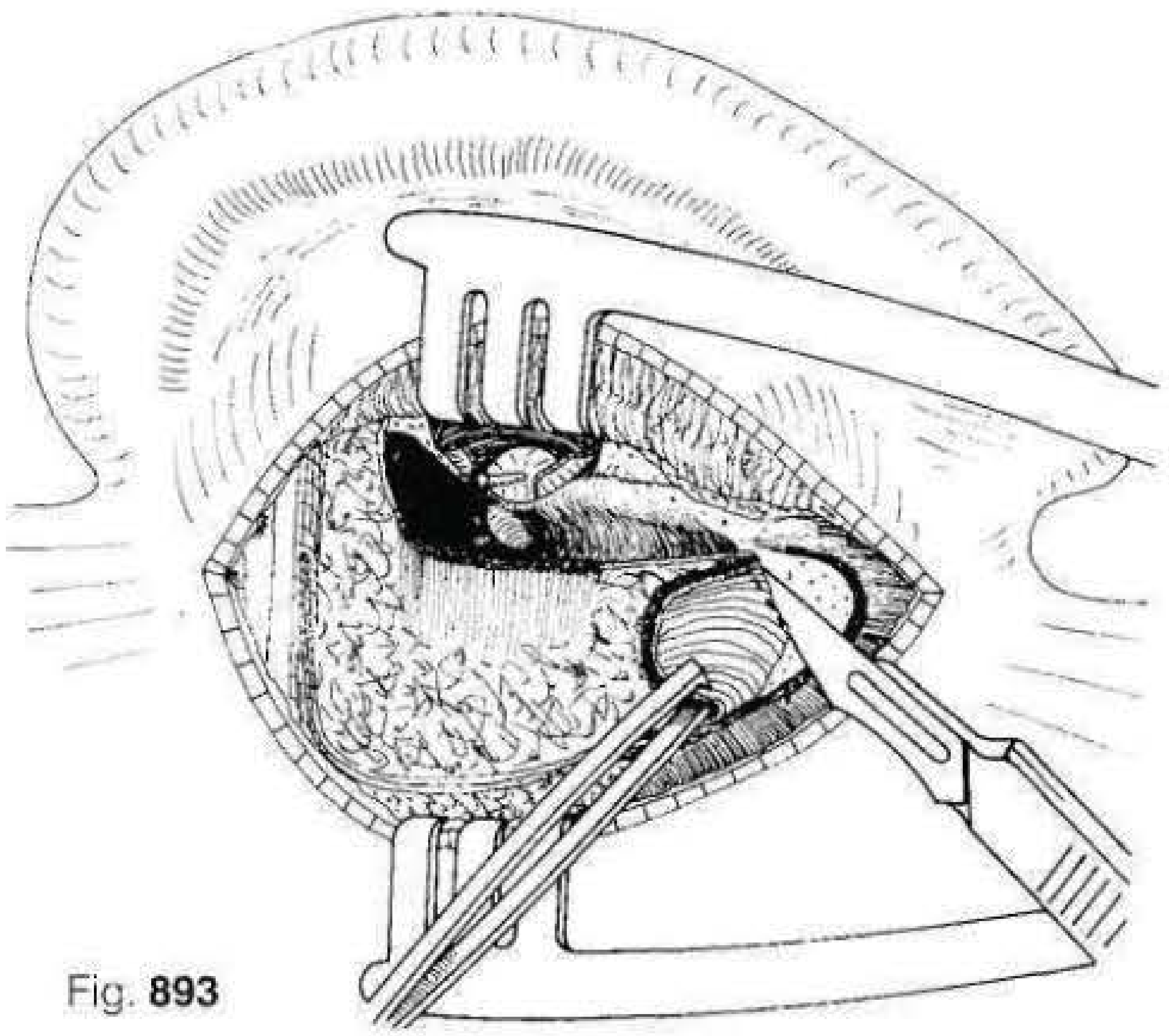


Fig. **893**

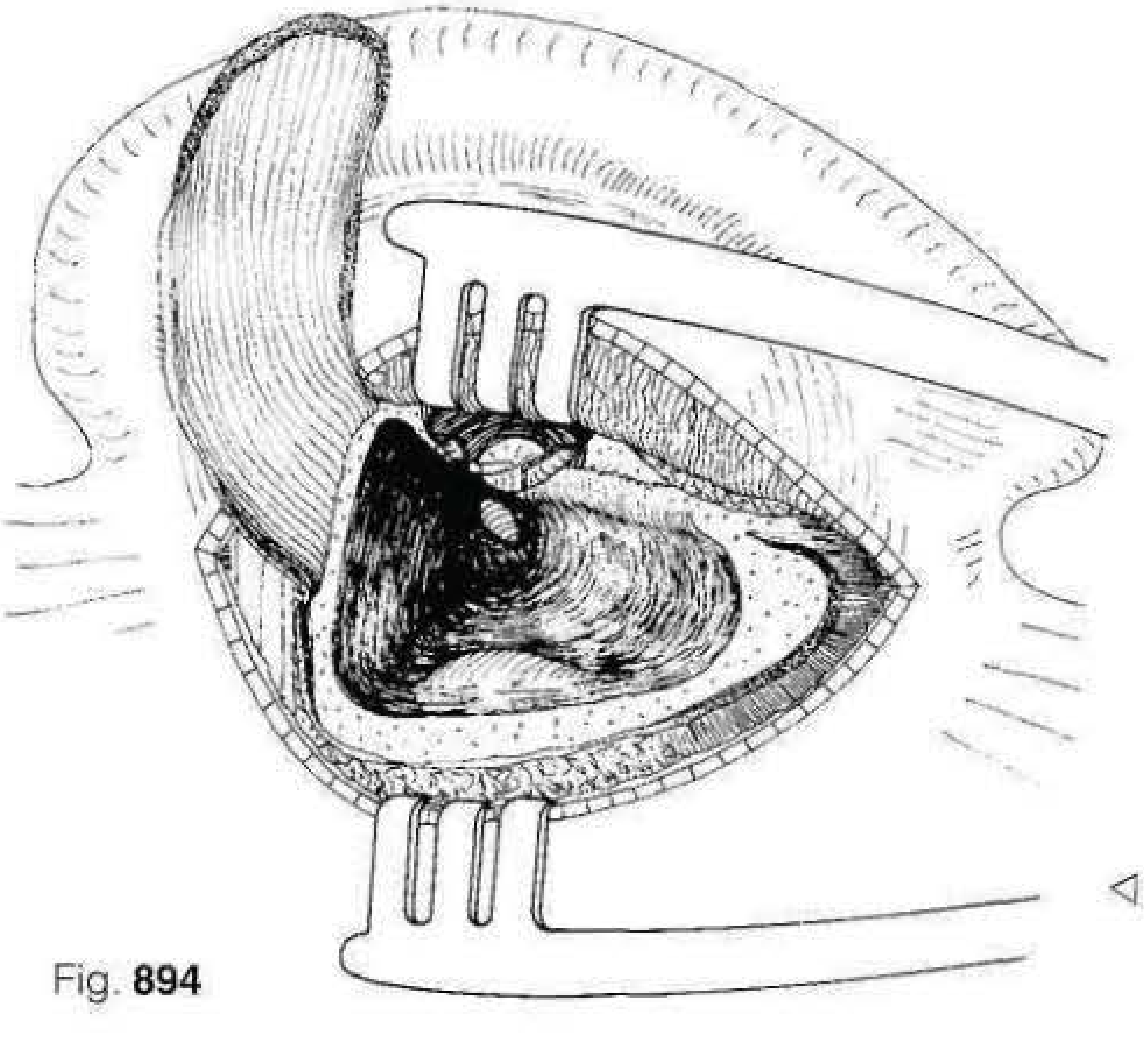


Fig. **894**

Fig. **893** **The Guilford superior pedicled flap.** After a canal wall–down mastoidectomy performed in an endaural approach, a retroauricular incision is made and the skin is elevated. The subcutis and periosteum is incised, starting at the inferior border of the temporalis muscle and continuing posteriorly and inferiorly. At the mastoid tip, the fibers of the sternocleidomastoid muscle are cut, and dissection of the flap is started. A canal wall–down mastoidectomy cavity is visible. The bridge is removed, and the malleus head is resected

◁ Fig. **894** The flap is elevated. It is pedicled antrosuperiorly. The periosteum is attached to the flap, and inferiorly the flap contains some muscle fibers

The Elbrønd Flap

The Elbrønd superiorly-based subcutis–periosteal flap (Elbrønd 1963) is a modification of Guilford's method (1960). The method is based on two approaches. First, the canal wall–down mastoidectomy is performed using an endaural approach. A retroauricular incision is then made (Fig. **896**) to harvest the subcutis–muscle–periosteum flap, which includes the superficial fibers of the sternocleidomastoid muscle, the splenius capitis muscle, the transversus capitis muscle, and the longissimus capitis muscle, as well as the fibrous tissue and the periosteum posterior to the cavity. After elevation of the skin with two additional retractors, the muscle fibers are cut with a scalpel directed tangentially toward the mastoid tip (Fig. **897**). All the fibers from the mastoid tip and the muscle fibers behind the mastoid tip are elevated and divided from their bony attachment. The flap is elevated in a superior direction, as far as the inferior border of the temporalis muscle (Fig. **898**), and placed in the cavity (Fig. **899**). It predominantly covers the posterior walls of the cavity, the sinodural angle, and the mastoid tip, but it does not reach the

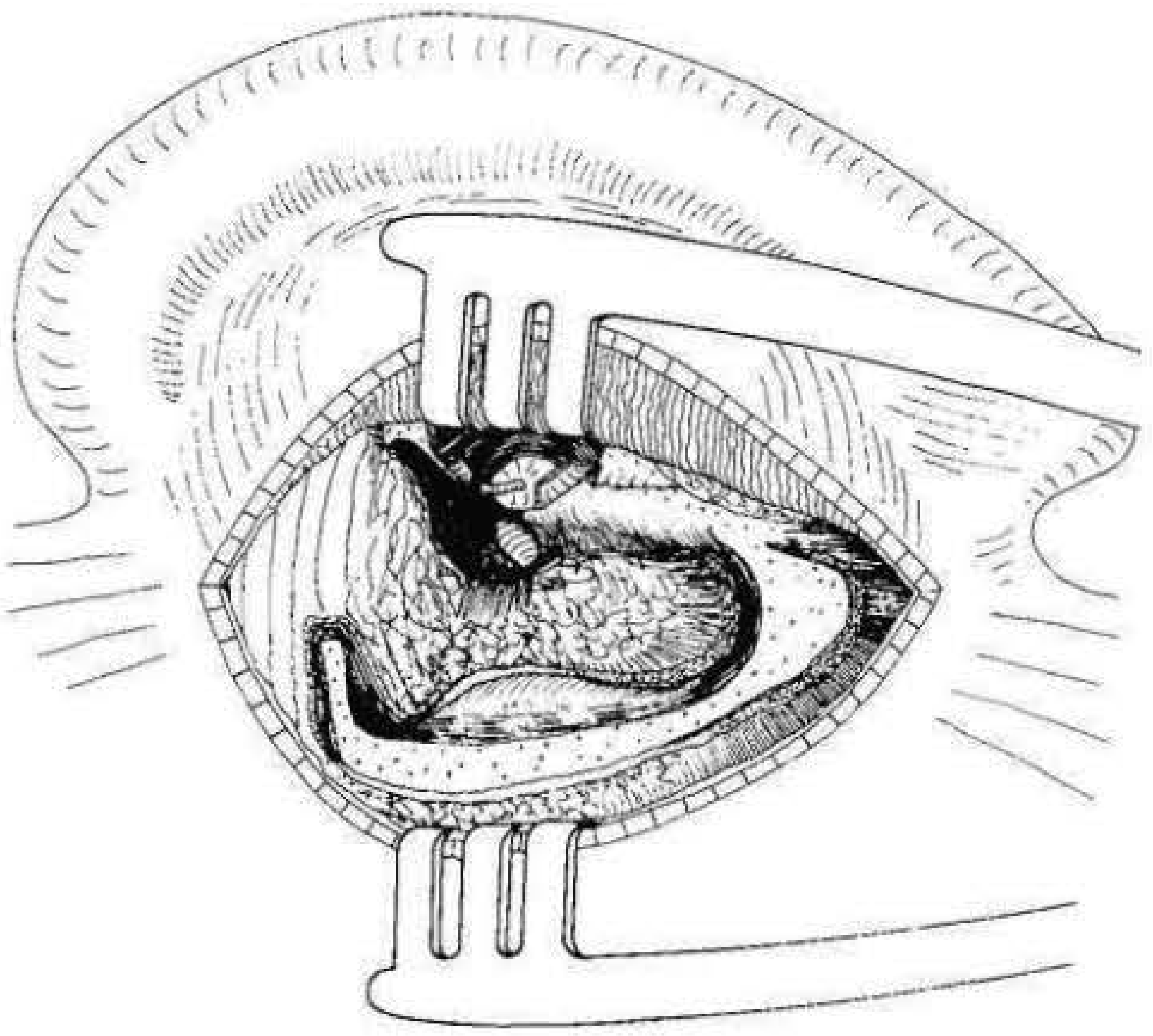


Fig. **895** The flap is placed in the cavity. It covers the mastoid tegmen and the medial aspect of the cavity, but in cannot totally obliterate the cavity

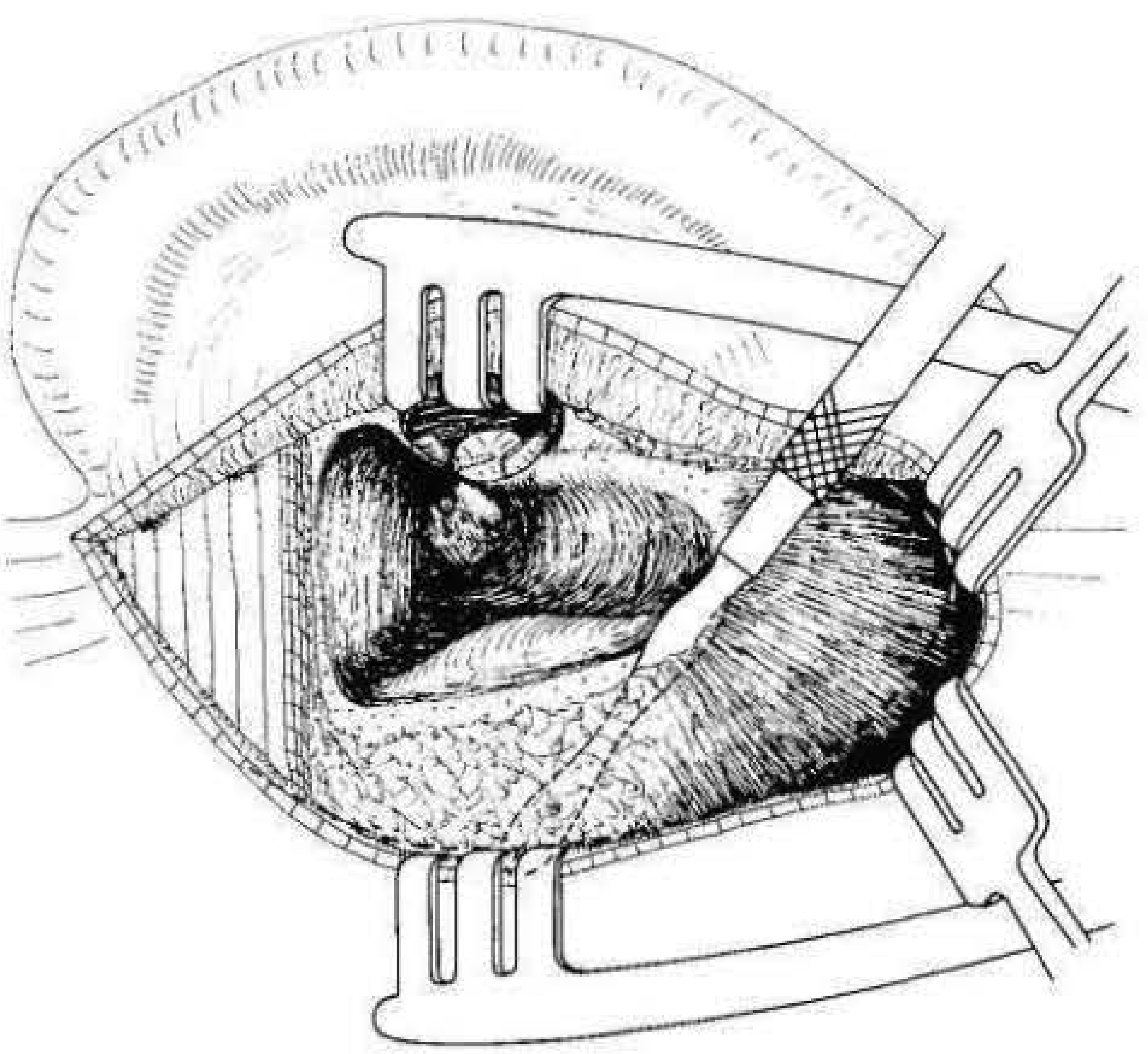


Fig. **896** **The Elbrønd superior pedicled flap.** A canal wall–down mastoidectomy in an endaural approach has just been performed. The tympanomeatal flaps are elevated, the malleus head is resected, the incus is extruded, and the bridge is removed. A retroauricular incision is performed, and the skin is elevated far posterior to the cavity. The subcutaneous tissue and periosteum is detached from the bone. The dashed line indicates the size of the flap, which involes the fibers of the sternocleidomastoid muscle, splenius capitis muscle, and transversus nuchae muscle

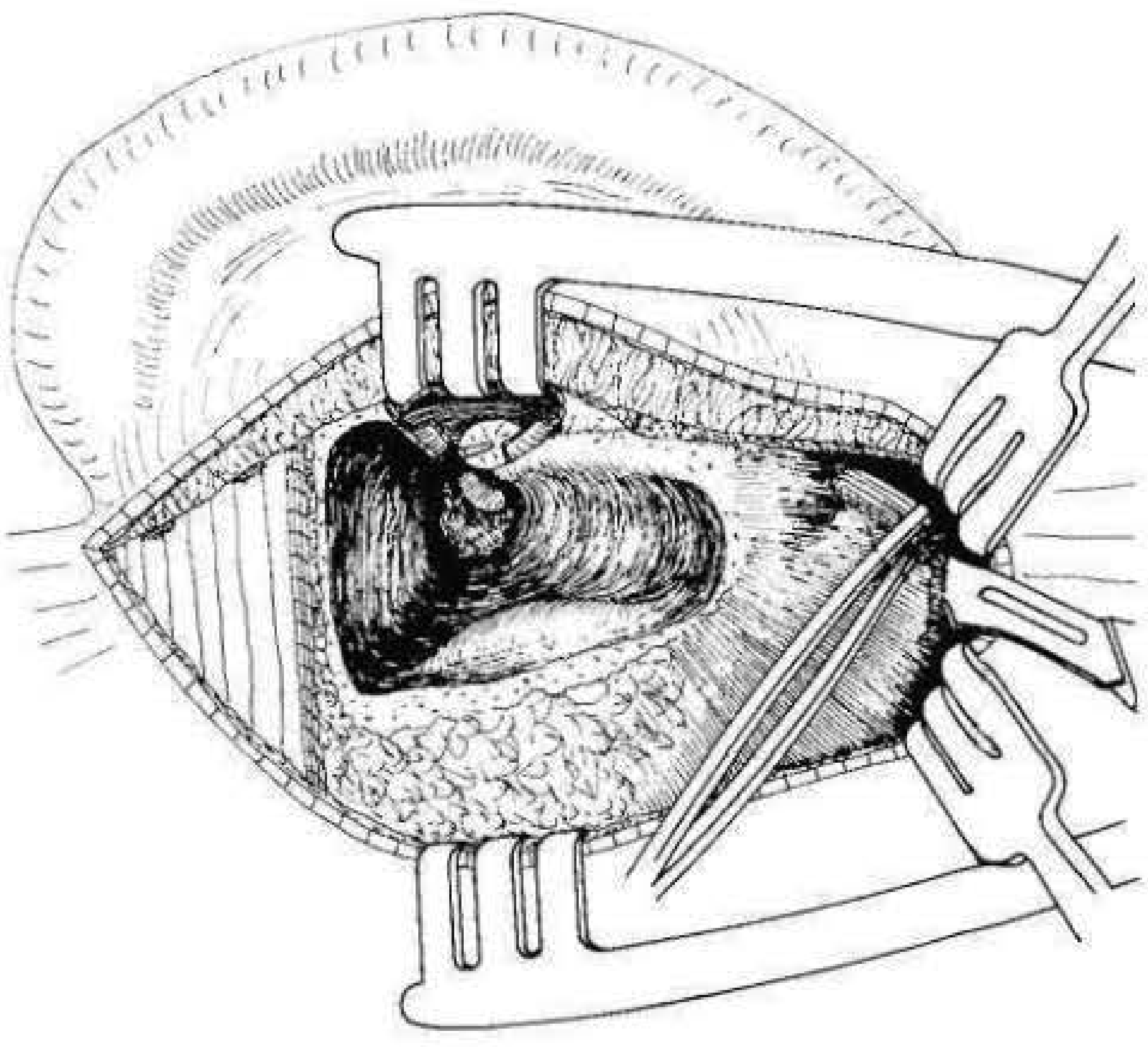


Fig. **897** The muscle fibers of the sternocleidomastoid muscle are cut with a scalpel directed tangentially toward the mastoid tip

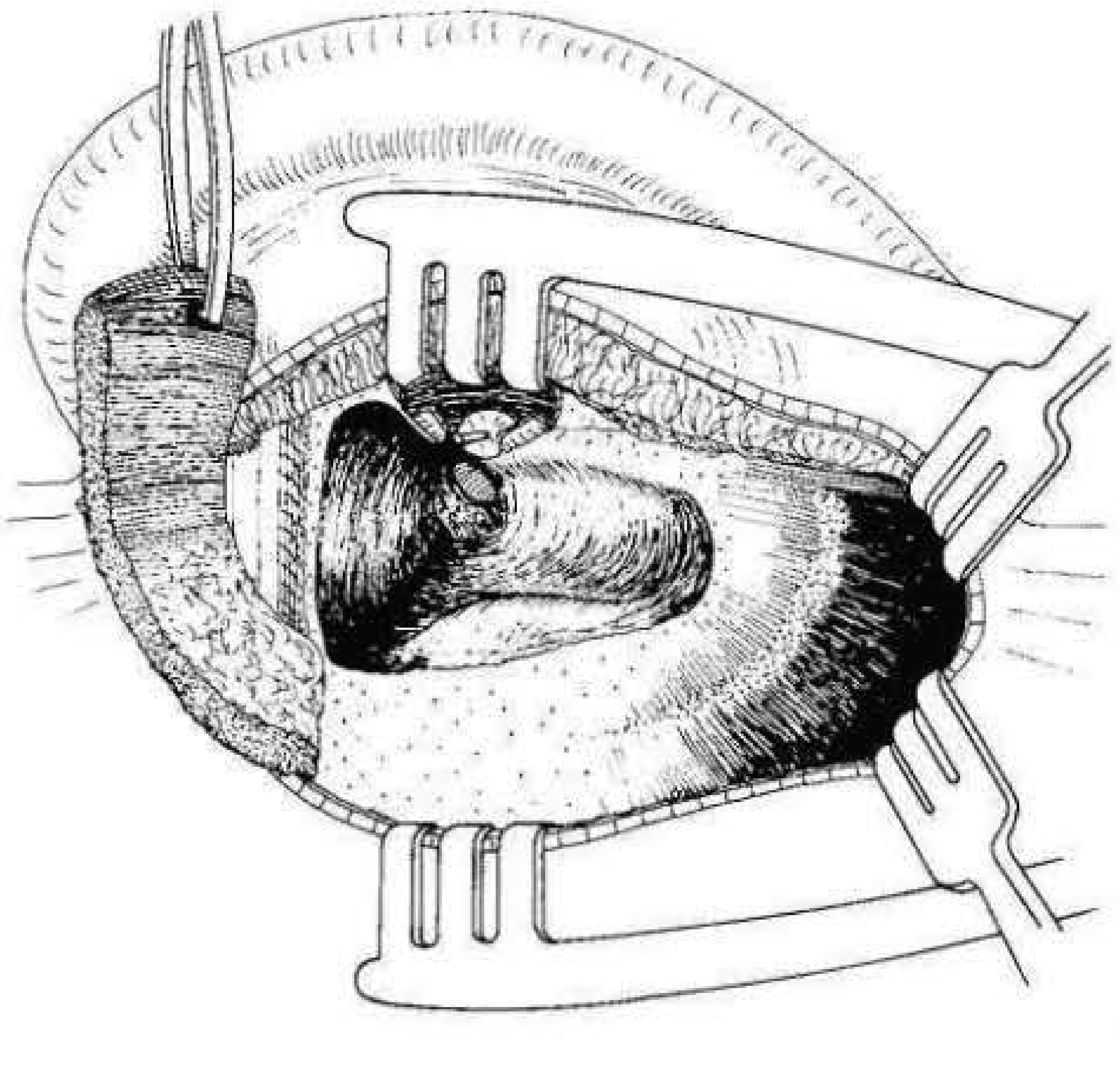


Fig. **898** The entire flap is elevated. Inferiorly, it mainly consists of muscles, while superiorly it consists of subcutaneous tissue and periosteum. It is pedicled posterosuperiorly

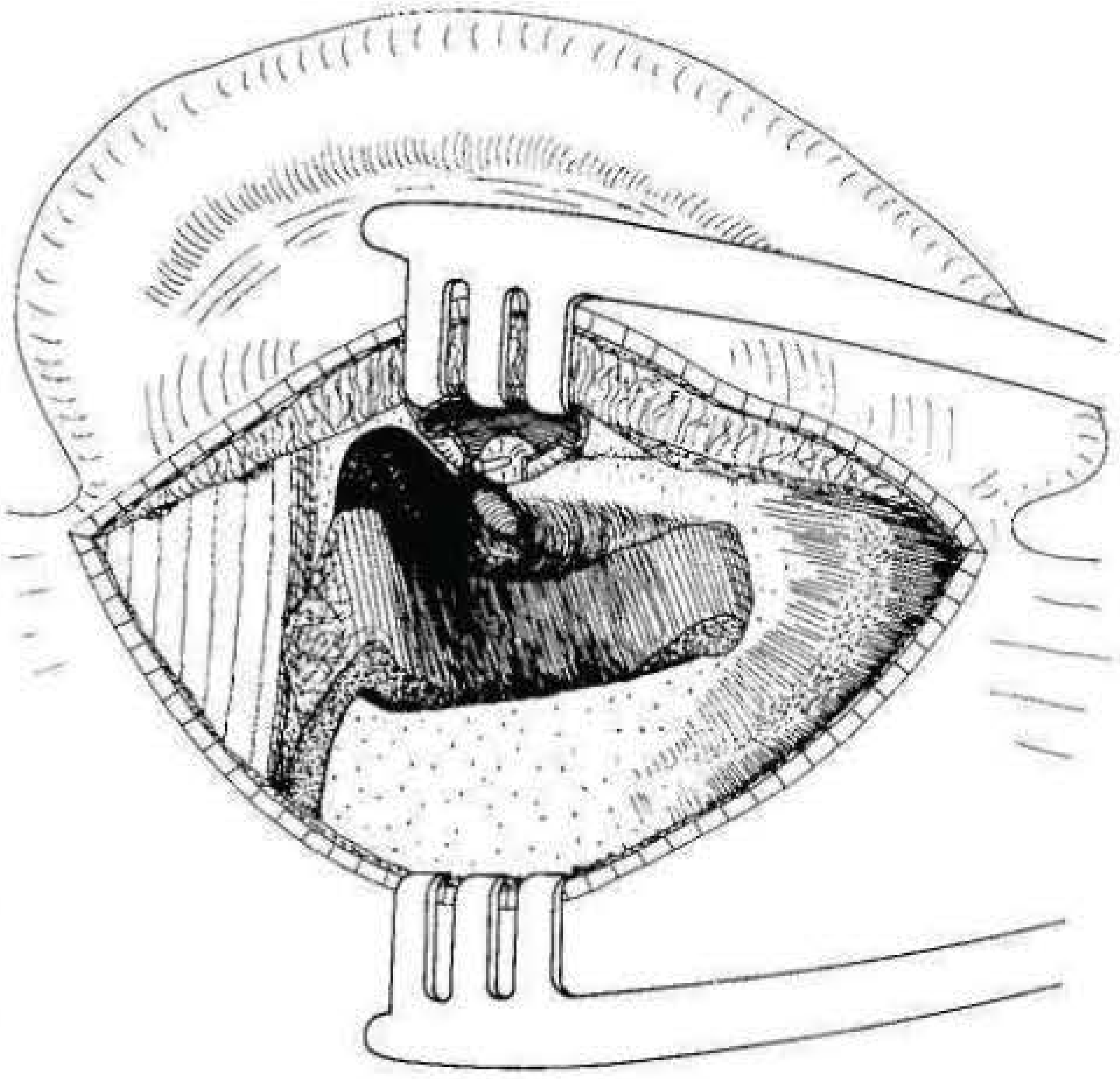


Fig. **899** The flap is placed in the cavity. It mainly covers the posterior walls of the cavity and the sinodural angle, as well as the mastoid tip

aditus ad antrum, the attic, or the lateral semicircular canal (Fig. **896**). Compared to the Guilford flap, the Elbrønd flap is larger, and its pedicle is placed further posteriorly.

The Turner Temporalis Muscle Double Flap

The principle of this modification of the Rambo technique is to raise enough temporalis muscle tissue to divide the muscle into two separate flaps. The first is anterosuperiorly based, consisting of the inferior part of the muscle and covering the mastoid tegmen and the anterosuperior part of the cavity. The other muscle flap consists of the superior part of the temporalis muscle. It is posterosuperiorly based, and obliterates the sinodural angle, the posterior part of the cavity, and the mastoid tip (Turner 1966, 1972).

The surgical technique for this method is, however, complex and time-consuming. It starts with a large endaural incision, with the vertical skin incision continuing above the pinna and around the postauricular region to the mastoid tip (Fig. **900**). It is similar to the Heermann C incision (Vol. 1, p. 24). and to the superior approach (Vol. 1, pp. 63–67), but Turner rotates the auricle completely out of the operating field. A large, laterally-based skin flap is elevated laterally, exposing the posterior ear canal. A swing-door technique with elevation of superior and inferior tympanomeatal flaps exposes the tympanic cavity (Fig. **901**). The incision goes through the anterior and superior auricular muscles, and allows extensive exposure of the temporalis muscle fascia by spreading the blades of a pair of Metzenbaum scissors two or three times in various directions. The upper half of the auricle is retracted posteriorly, and the root of the helix along the conchal cartilage is freed from the mastoid process. The auricle is now completely rotated except for a 3.5–4.0-cm pedicle extending from the anterior border of the mastoid tip to the tragus (Fig. **902**). After harvesting of the fascia and after a canal wall–down mastoidectomy, the anterosuperiorly-based temporalis muscle flap is cut out and elevated (Fig. **903**). The anterior flap is placed in the cavity, and the posterior flap is then elevated. This elevation extends to the inferior edge of the temporalis muscle and to the occipitomastoid suture (Fig. **904**). Finally, the posterosuperiorly-based flap is placed in the cavity, covering the posterior part of the mastoid tegmen, the sinodural angle, and the posterior wall of the cavity (Fig. **905**). The auricle is replaced, and the fascia is placed under the drum remnant. The tympanomeatal flaps are replaced, covering the muscle flaps. The laterally-based conchal canal skin flap is replaced in such a way that it covers the muscle and maintains a wide ear canal (Fig. **906**).

Fig. **900** **The Turner temporalis muscle double flap.** An endaural approach, with a lateral circumferential incision and radial incisions at the 6-o'clock and 12-o'clock position is made. The vertical incision goes far around the pinna, through the postauricular region, to the mastoid tip

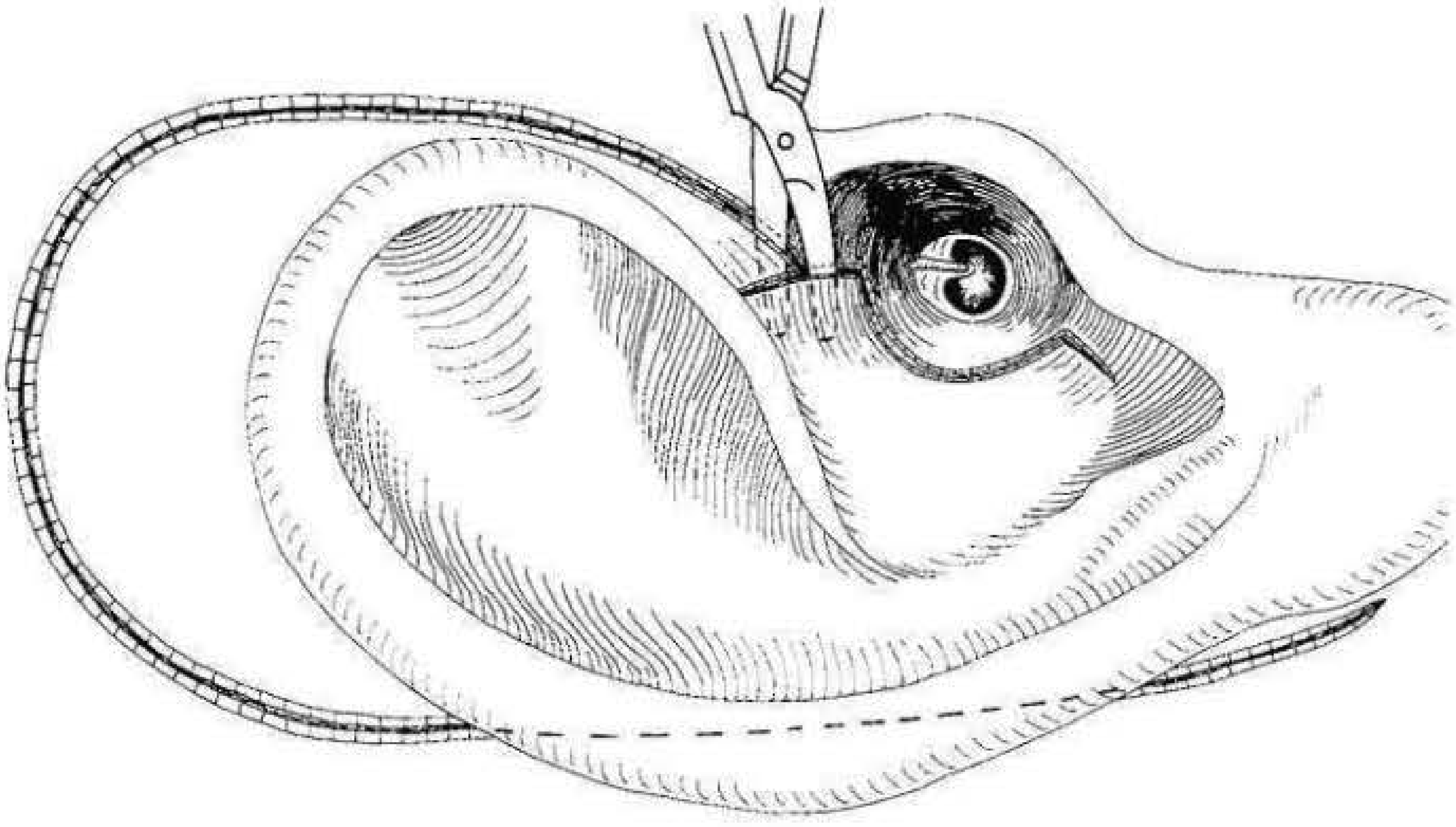


Fig. **901** A laterally-based conchal flap is elevated. The pinna is liberated from the temporalis muscle fascia after the blades of a pair of Metzenbaum scissors have been spread two or three times in various directions. In the tympanic cavity region, the tympanomeatal flap is cut at the 9-o'clock position. Superior and inferior skin flaps are elevated, exposing the edges of the total perforation

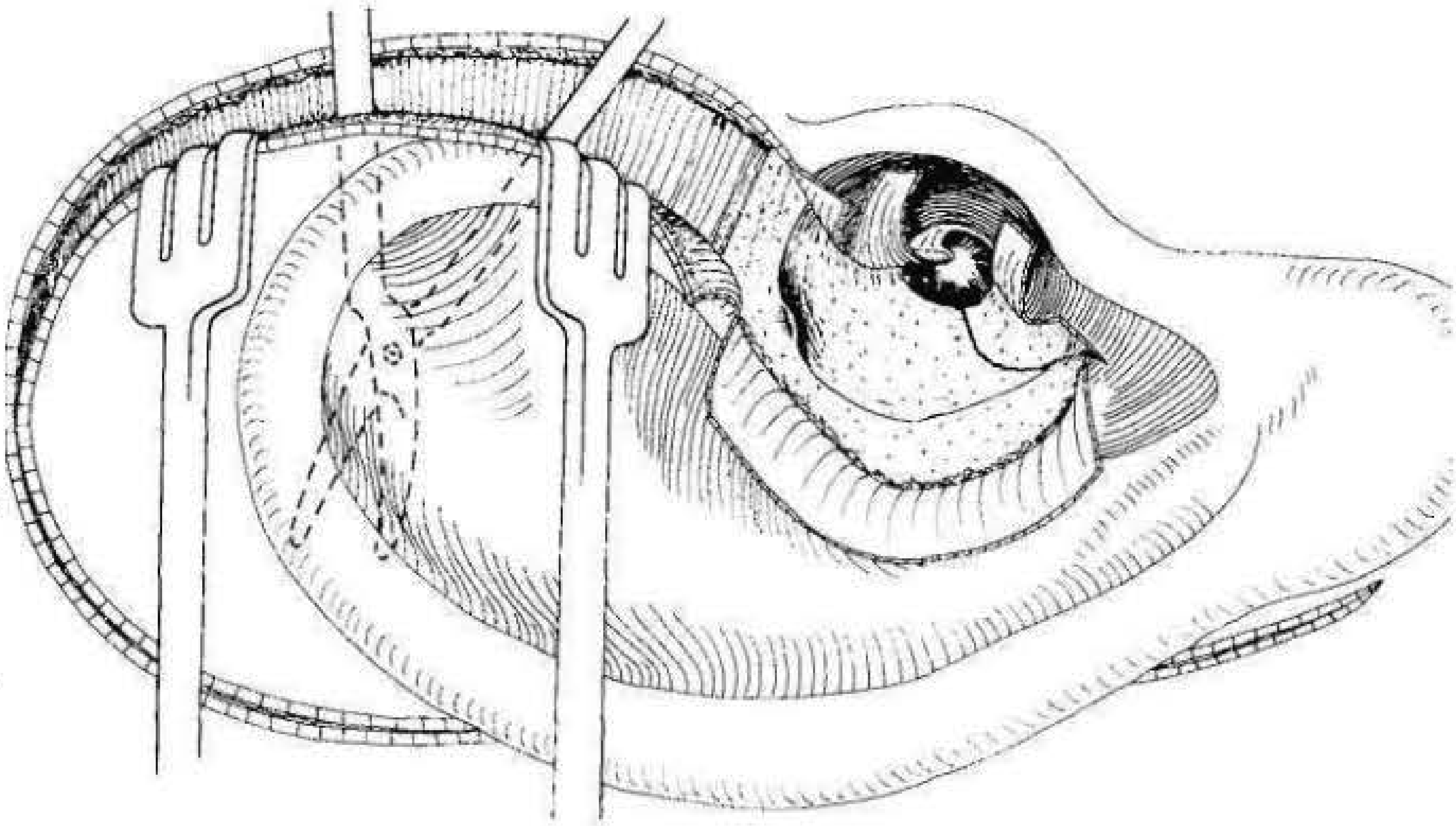
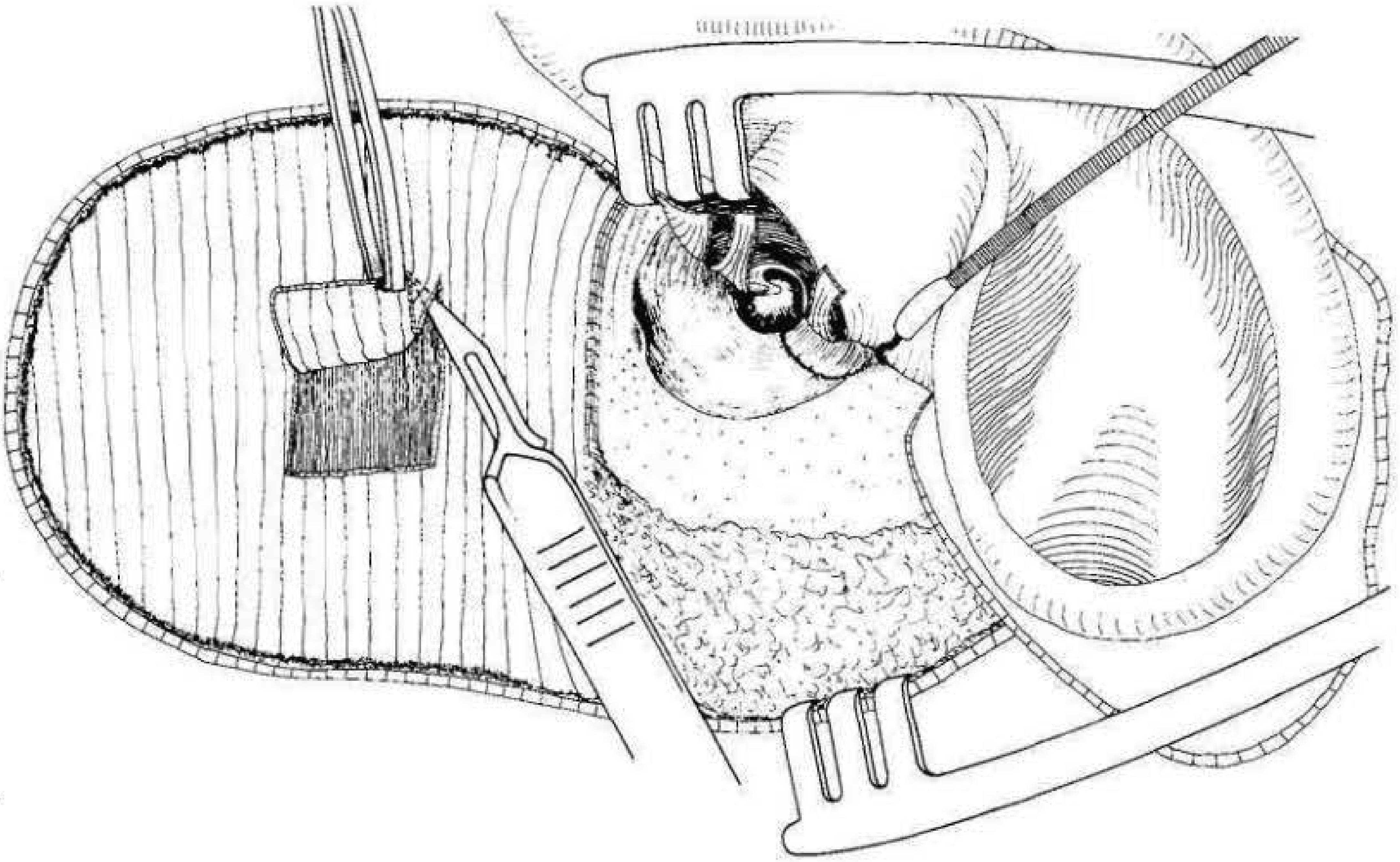


Fig. **902** After it has been totally freed, the auricle is rotated out of the operating field, but remains attached to the anterior part of the ear canal, with a 3–4 cm–long pedicle extending from the anterior border of the mastoid tip to the tragus. A large area of the temporalis muscle is exposed, and a large piece of fascia is harvested



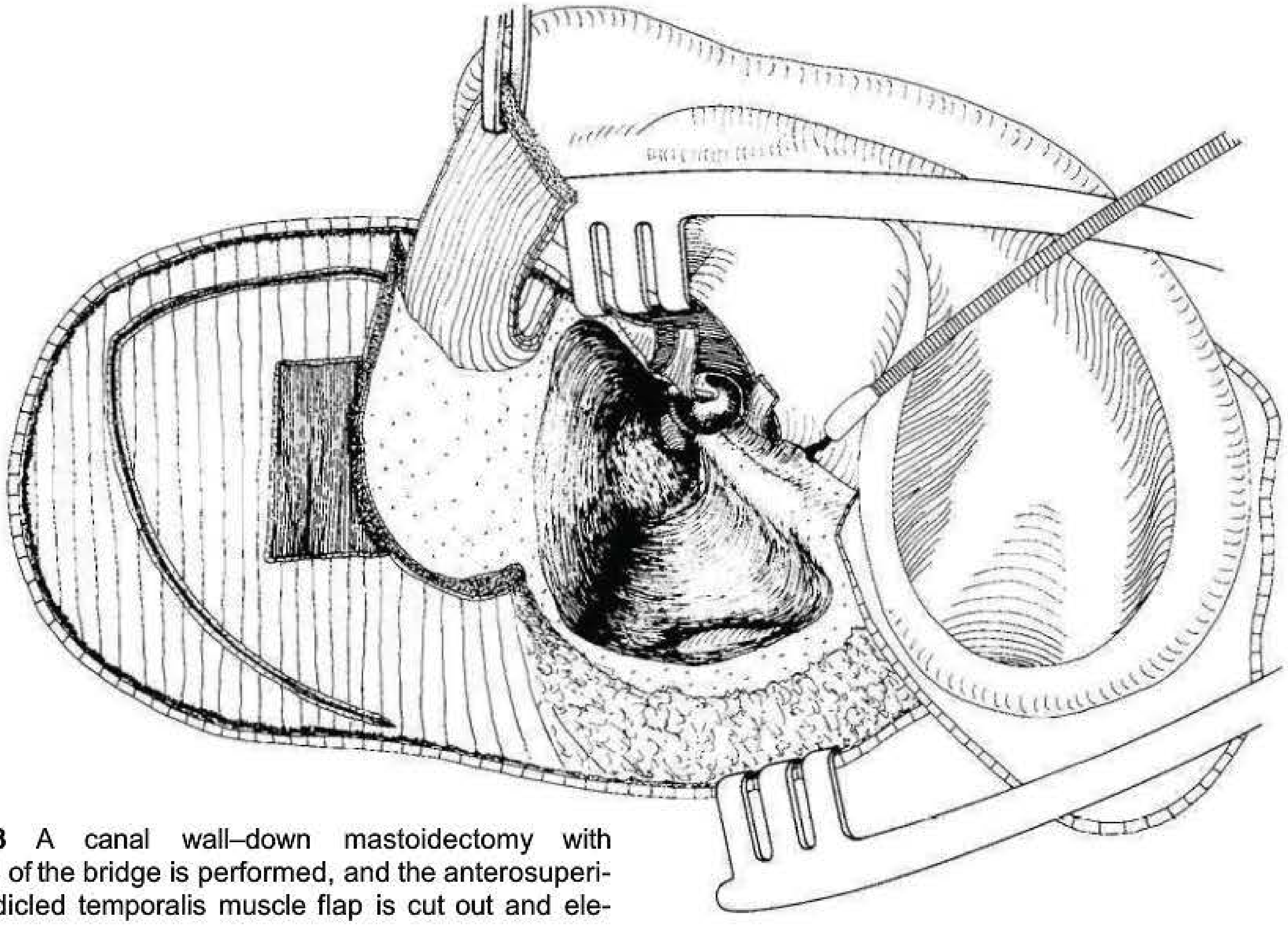


Fig. **903** A canal wall–down mastoidectomy with removal of the bridge is performed, and the anterosuperiorly-pedicled temporalis muscle flap is cut out and elevated

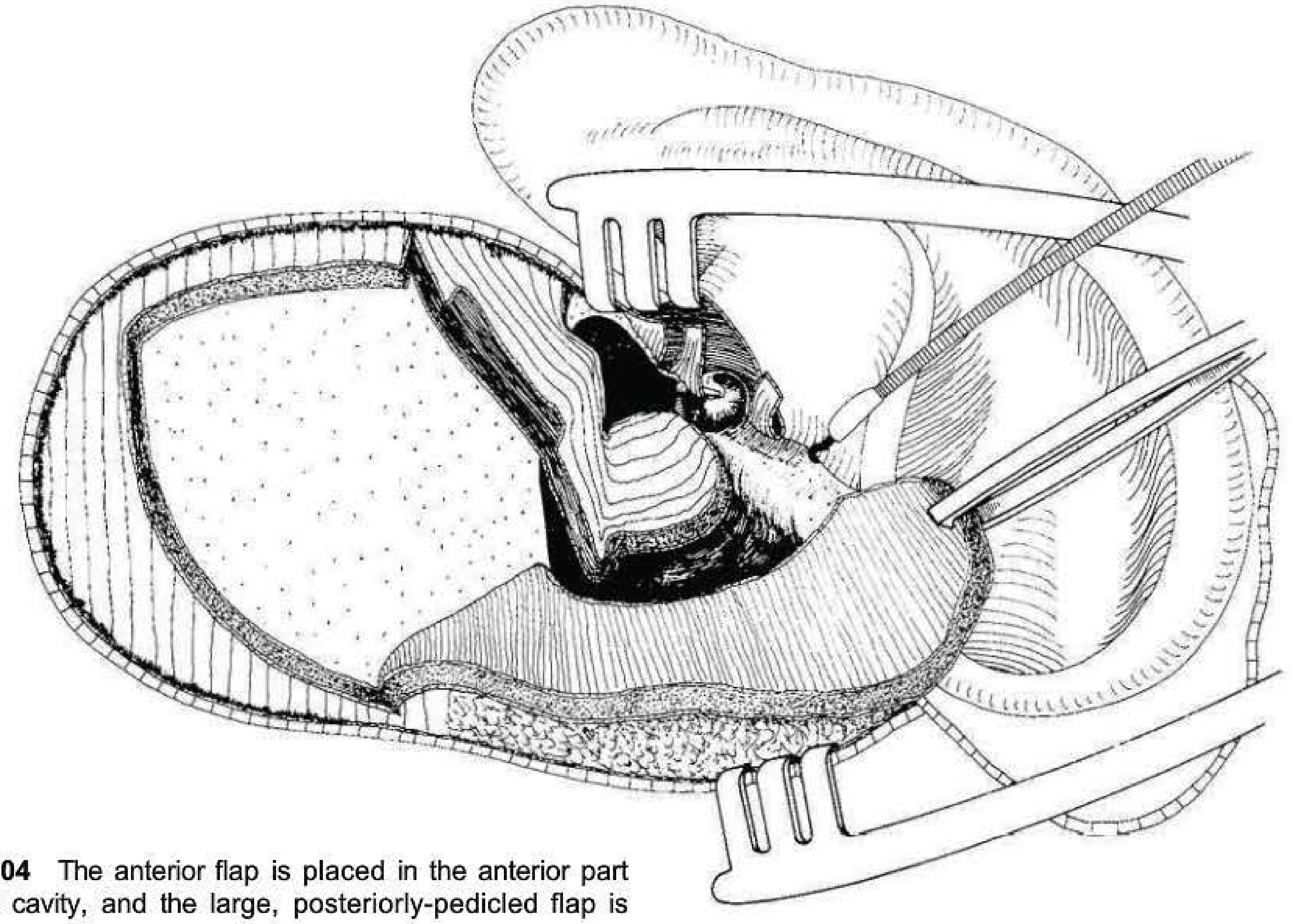


Fig. **904** The anterior flap is placed in the anterior part of the cavity, and the large, posteriorly-pedicled flap is elevated

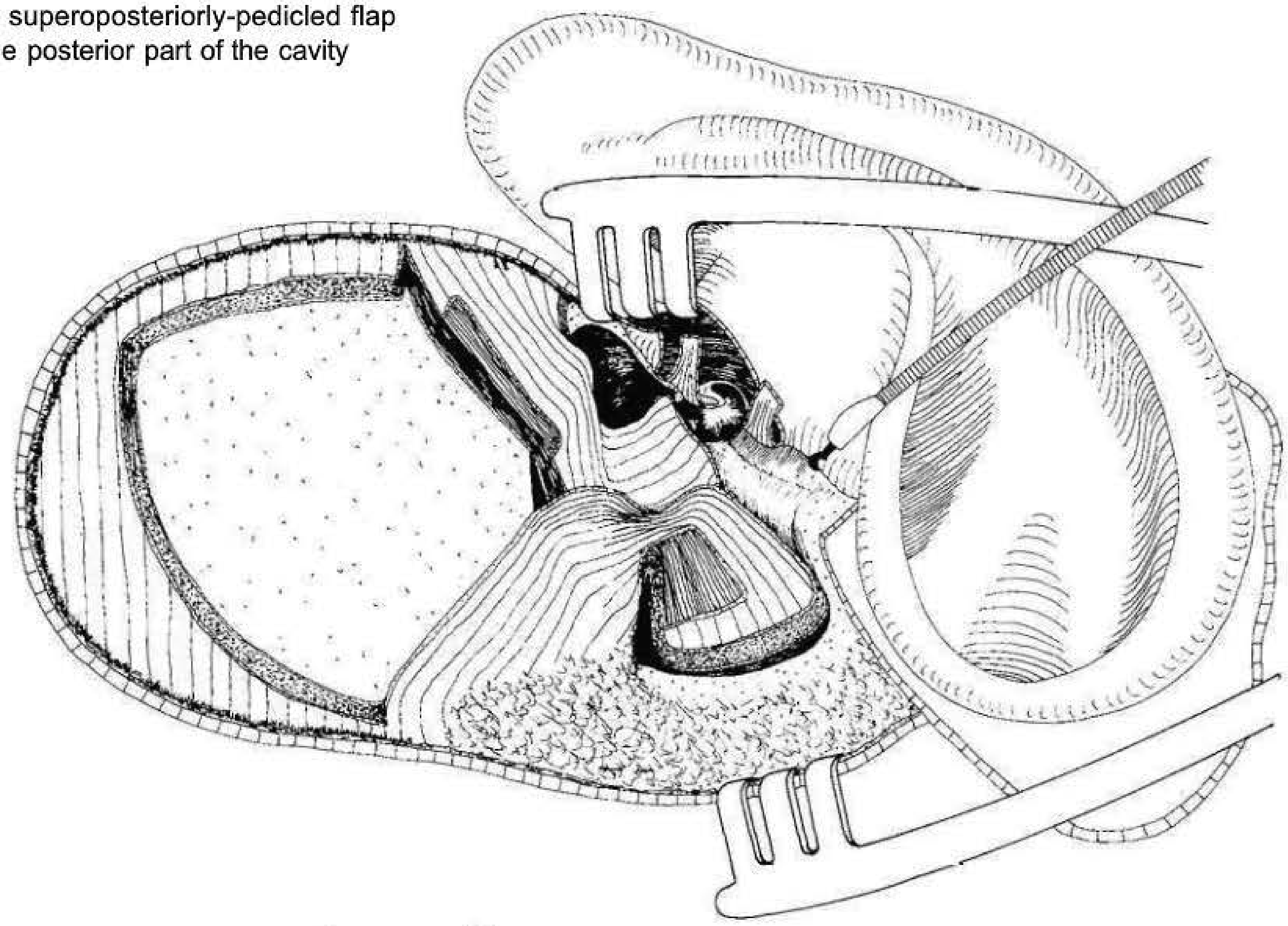


Fig. **905** The superoposteriorly-pedicled flap is placed in the posterior part of the cavity

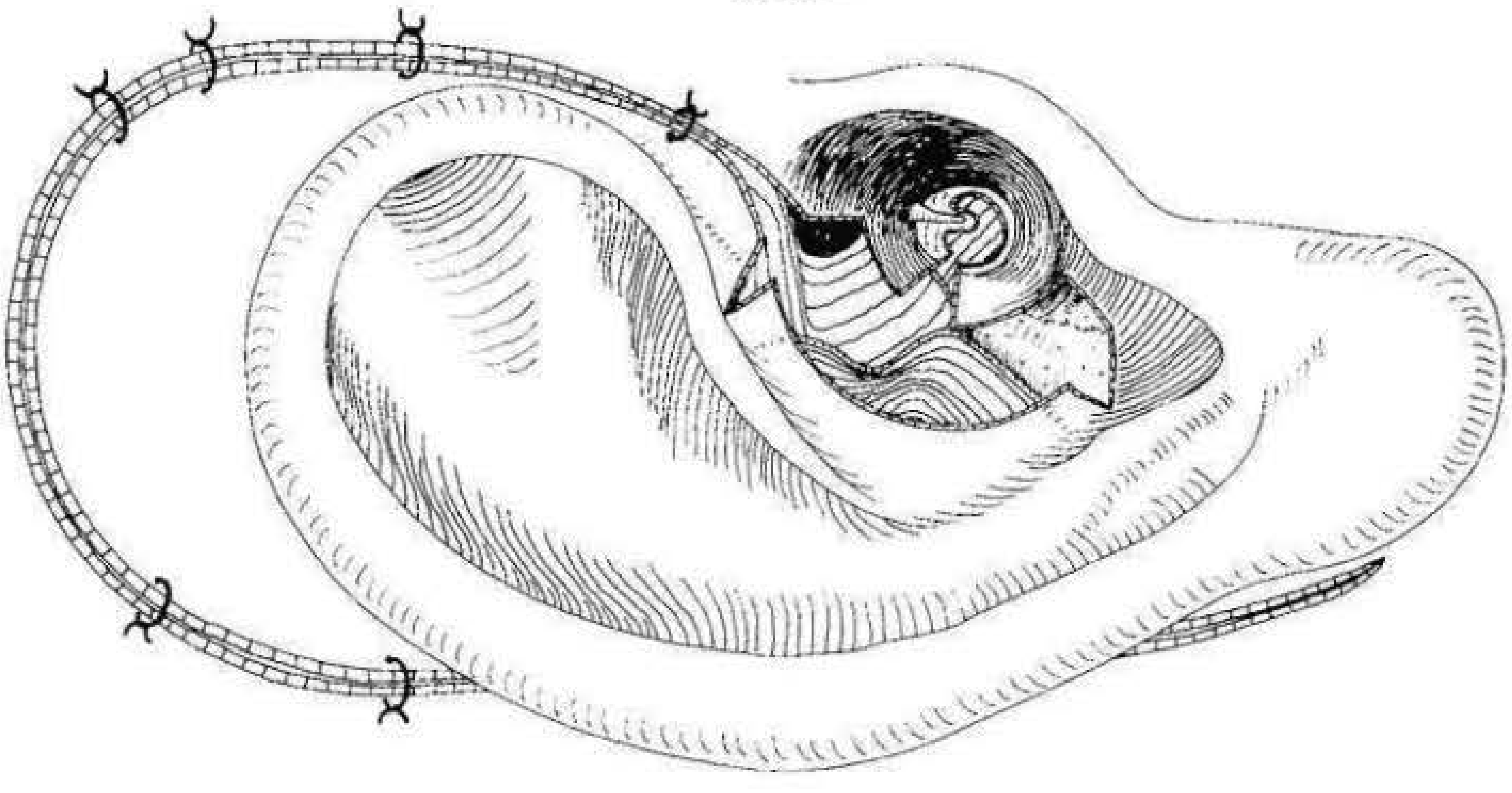


Fig. **906** The auricle is replaced and partly sutured. The subtotal perforation is covered with an underlay fascial graft, and the tympanomeatal flaps are replaced, partly covering the anterior muscle **flap.** The conchal flap is replaced, and the ear canal is widened

Posterosuperiorly Based Musculofascial Flap

For reconstruction of old radical cavities, Dawlatly (1992) described an obliteration technique using part of the temporalis muscle pedicled posterosuperiorly, along with fibrous tissue and periosteum. After a large S-shaped retroauricular skin incision (Fig. **907**), a large area of temporalis muscle fascia is exposed (Fig. **908**). A piece of fascia is dissected and partly elevated. The fascia is still partly attached to the muscle, and will be used to cover the drum region (Fig. **909**). Using cutting diathermy, a circular piece of the temporalis muscle is developed and elevated together with the periosteum to a level 1 cm inferior to the lower edge of the muscle. The posterosuperior pedicle is composed of subcutaneous tissue, fibrous tissue, and the periosteum, its vascularization coming from the occipital artery (Fig. **910**). The flap is placed in the cavity, and covers its posterior wall and the antrum (Fig. **911**). The pedicled fascial graft then covers the tympanic cavity region (Fig. **912**).

The use of pedicled fascia is unnecessary, and a free fascial graft is easier to handle. There is no evidence of better survival for pedicled fascia as an ear drum graft when compared with a free fascial graft.

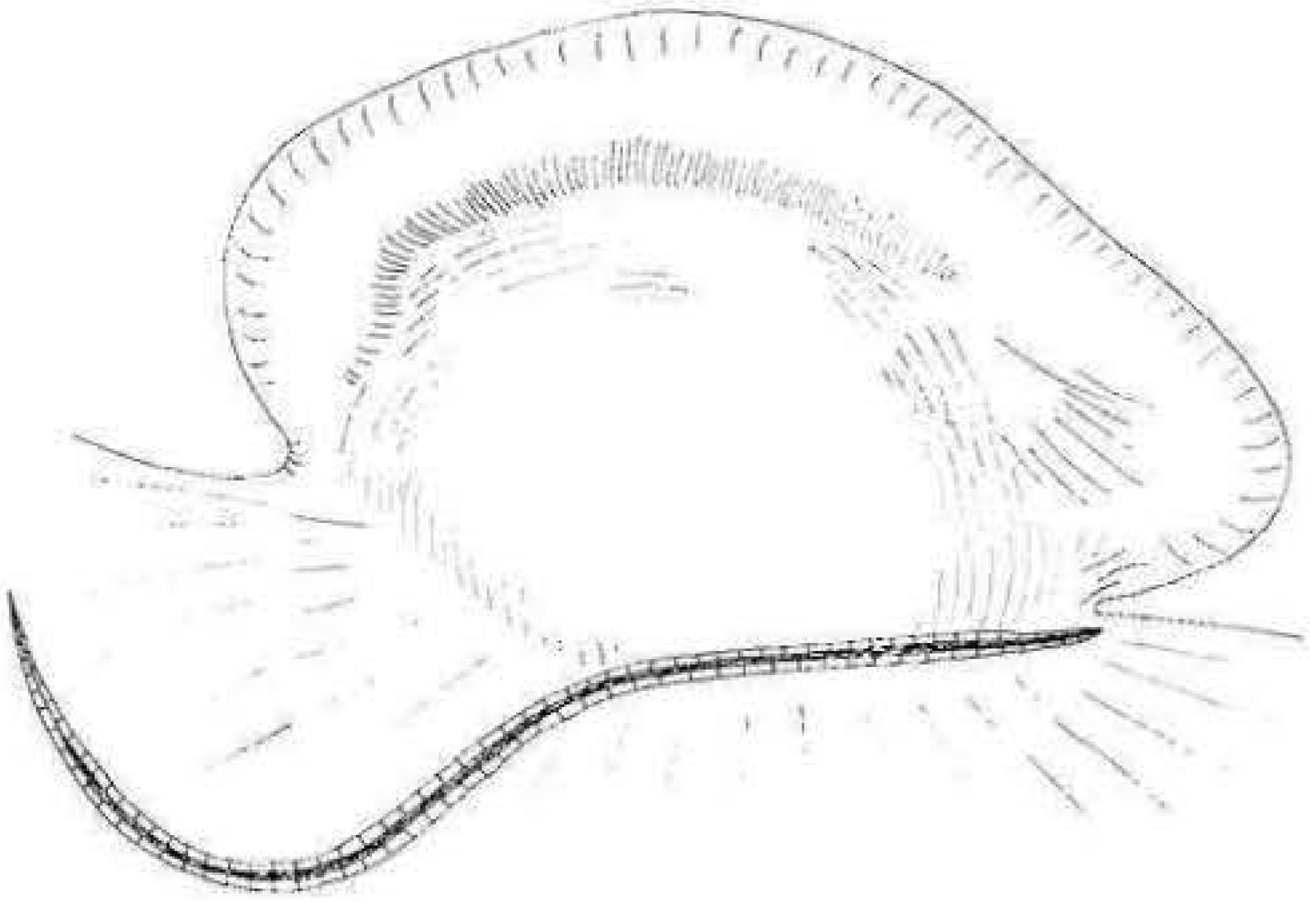


Fig. **907** **Superoposteriorly pedicled musculofascial flap** (Dawlatly). A large S-shaped retroauricular incision is made

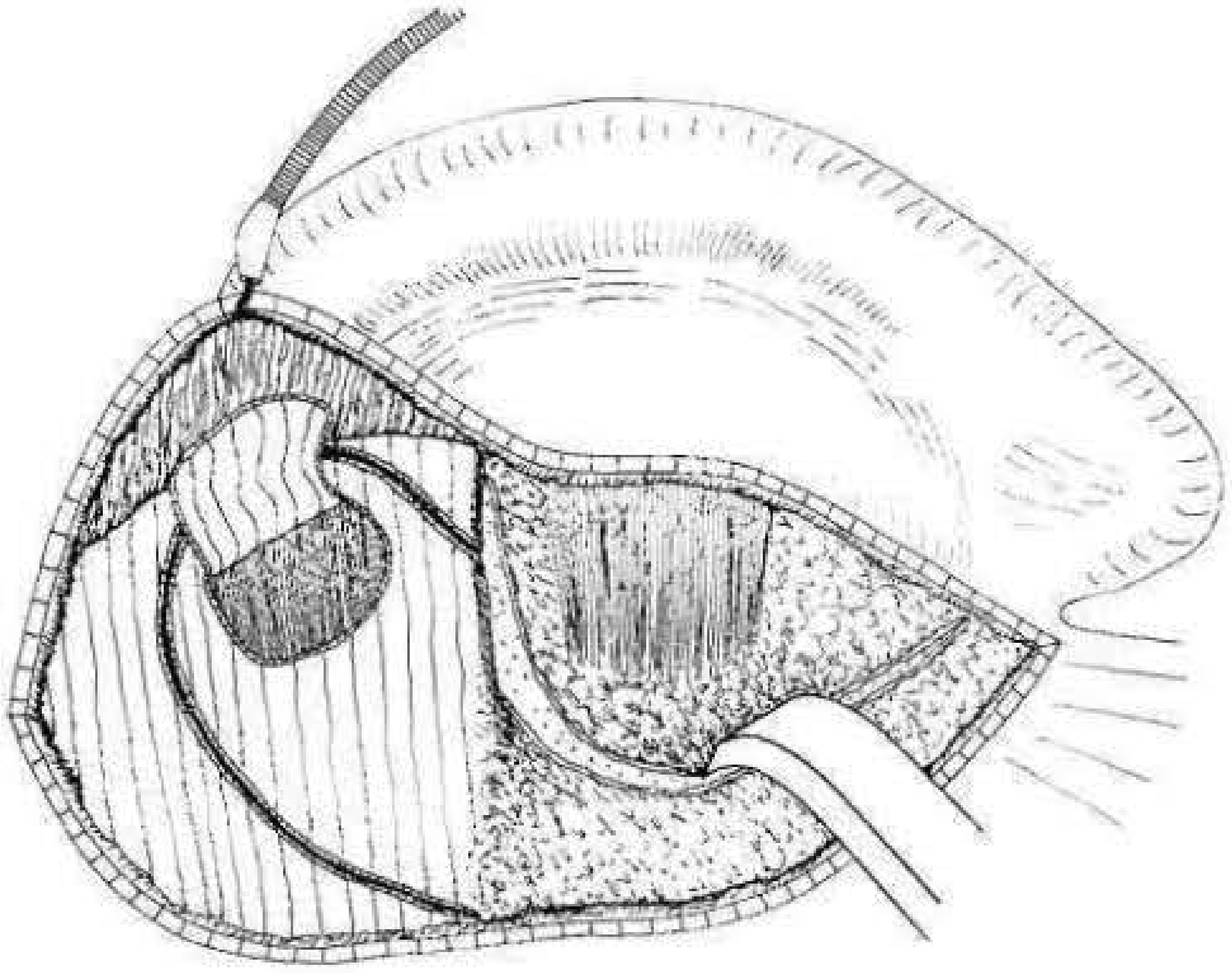


Fig. **908** The skin is maximally elevated. An incision is made around the ear canal, through the subcutaneous tissue in the periosteum, exposing the mastoid process. With a cutting diathermy, a large, round piece of temporalis muscle with a posterior pedicle is developed.
A piece of fascia is partly elevated

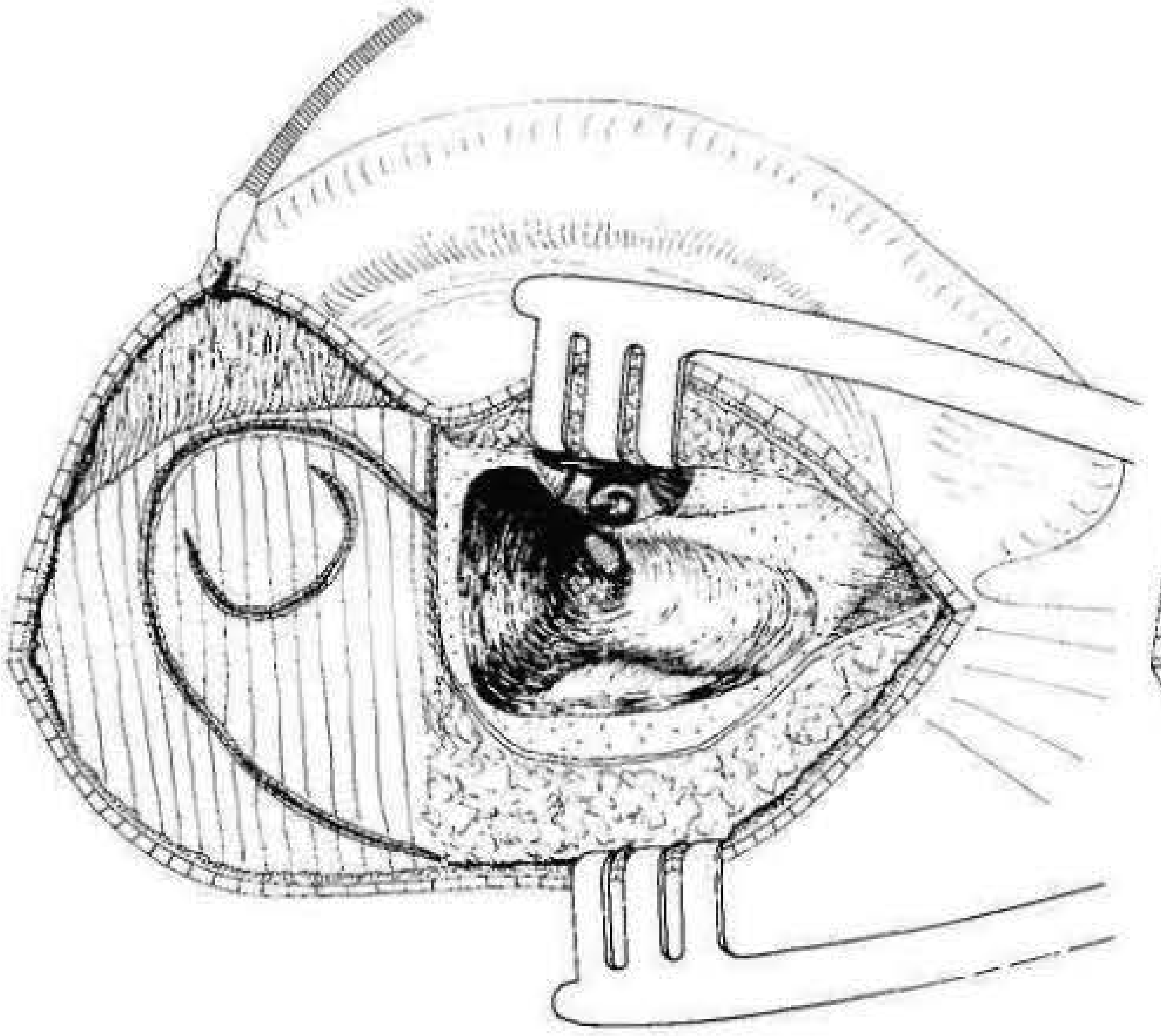


Fig. **909** A canal wall–down mastoidectomy is performed. The tympanomeatal flap is cut at the 9-o'clock position, and superior and inferior skin flaps are elevated

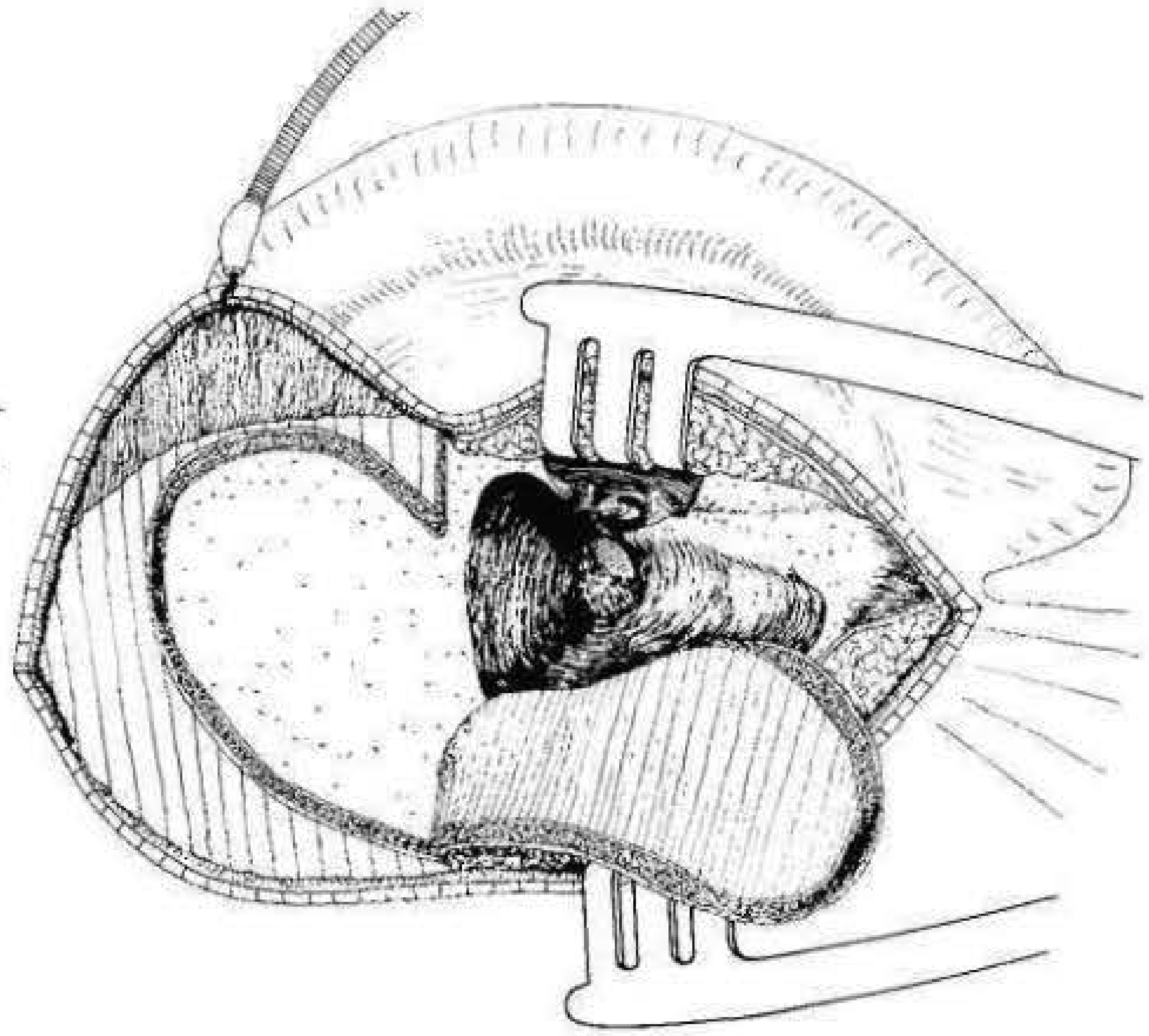


Fig. **910** The posteriorly-pedicled temporalis muscle flap is elevated

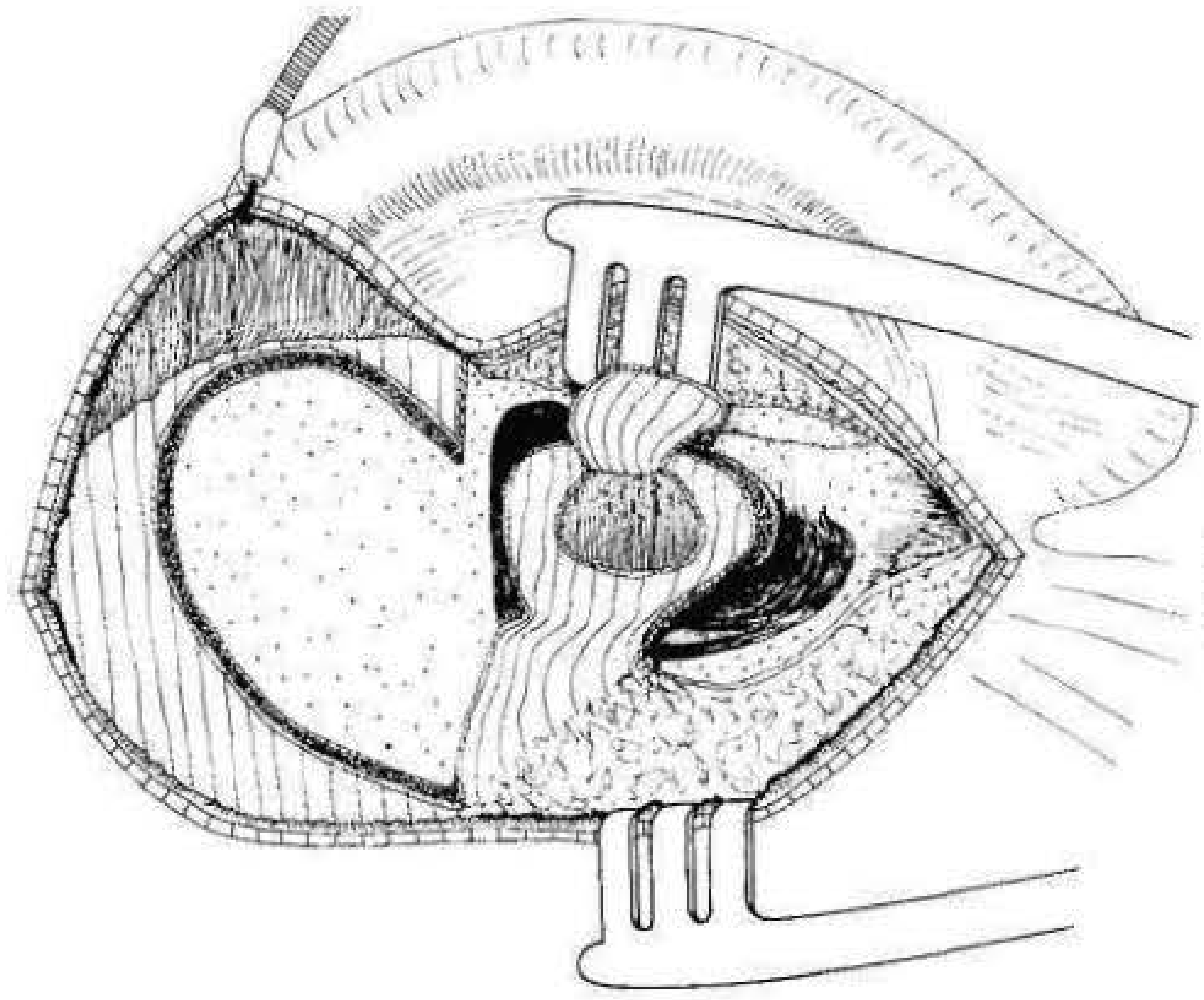


Fig. **911** The muscle flap is placed in the cavity, covering the attic, antrum, and sinodural angle. The pedicled fascia flap is used as an underlay graft

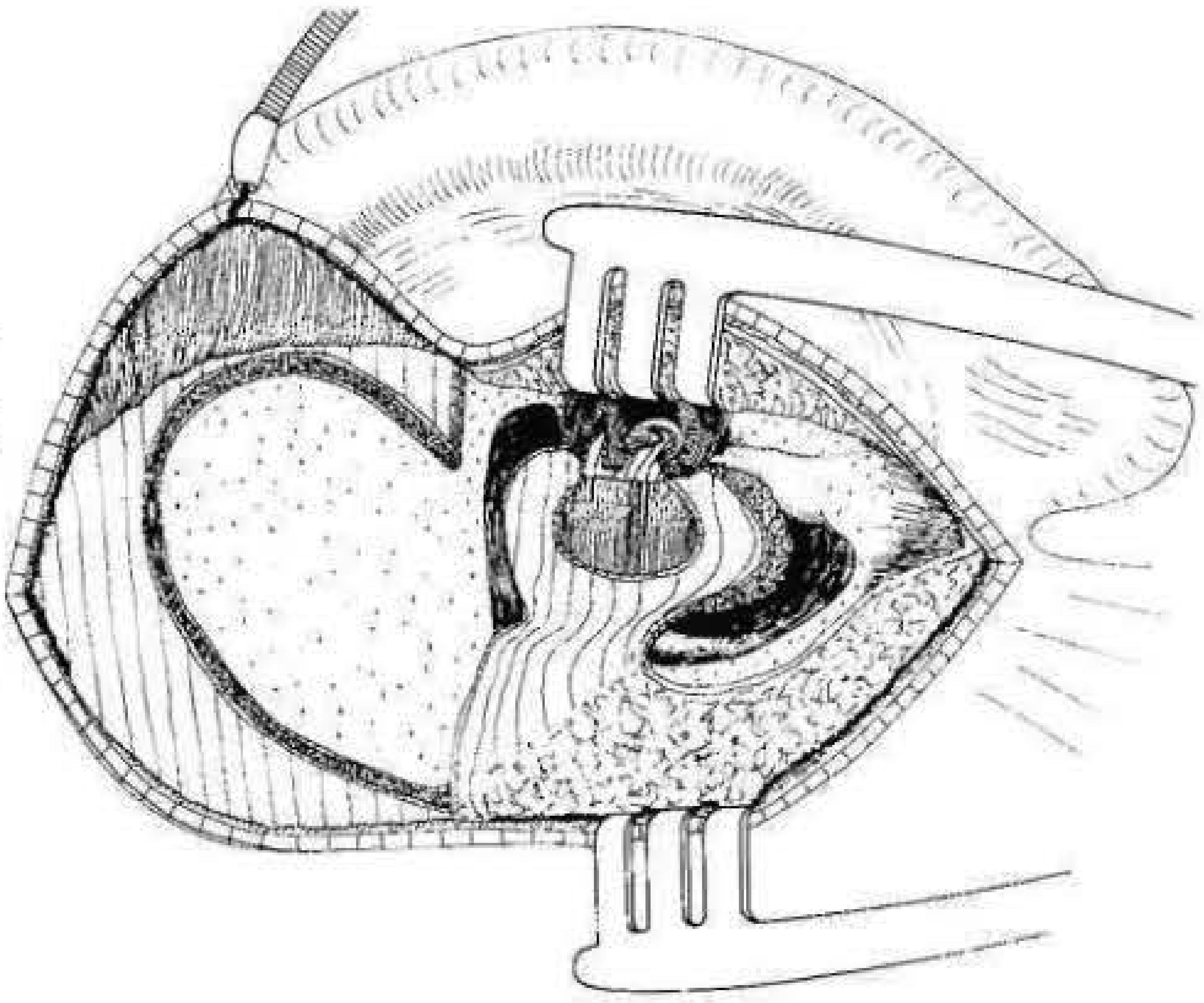


Fig. **912** The pedicled fascia graft is placed under the total perforation, and the canal skin flaps are replaced. They partly cover the muscle flap

Whitcher's Tripartite Flap

The Whitcher flap is anterosuperiorly based, and consists of three flaps: a small one for the anterior part of the mastoid tegmen and tympanic cavity, a large one for rebuilding the ear canal, and a minor one for the posterior part of the cavity (Whitcher and Streit 1963, Whitcher et al. 1966:).

Using an endaural approach, extending over the auricle (Fig. **913**), the temporalis muscle fascia is exposed. A canal wall–down mastoidectomy is performed (Fig. **914**). Using an incision along the posterior insertion of the temporalis muscle, continuing along its superior insertion anteriorly, a large piece of temporalis muscle is freed. A small flap for the tympanic cavity and two flaps for the mastoid cavity are elaborated; all three are anterosuperiorly based. The smallest flap covers the most anterior part of the cavity and the tympanic cavity (Fig. **915**). A large oval flap makes up the posterior ear canal wall, and obliterates most of the cavity. The most superior part of the temporalis muscle flap is used to obliterate the sinodural angle. The canal skin flaps are replaced, thus maintaining a wide ear canal.

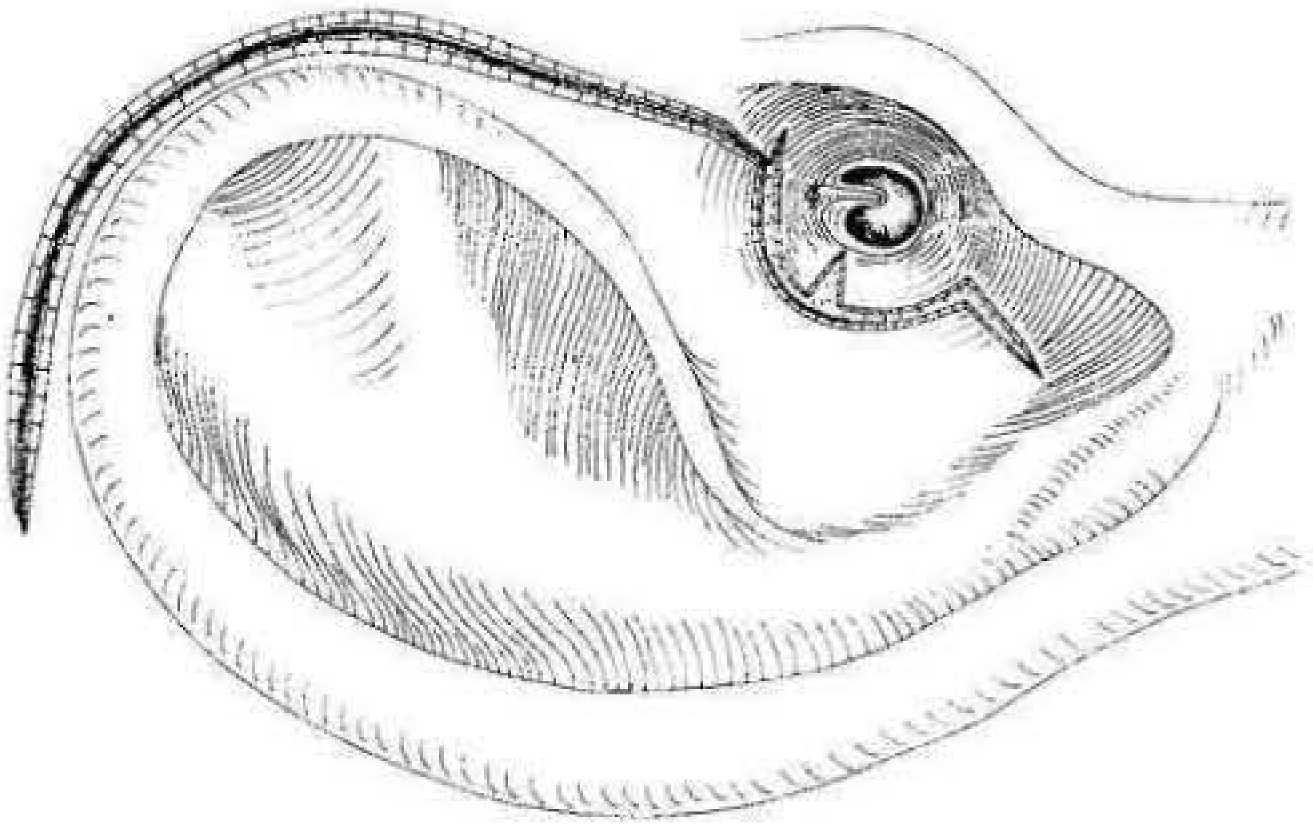


Fig. **913** **Whitchers's tripartite flap obliteration method.** An endaural approach with an intercartilaginous incision, a lateral circumferential incision between the 12-o'clock and 6-o'clock positions, a lateral radial incision at the 6-o'clock position, and a medial radial incision at the 9-o'clock position, are performed. The vertical incision extends over the auricle

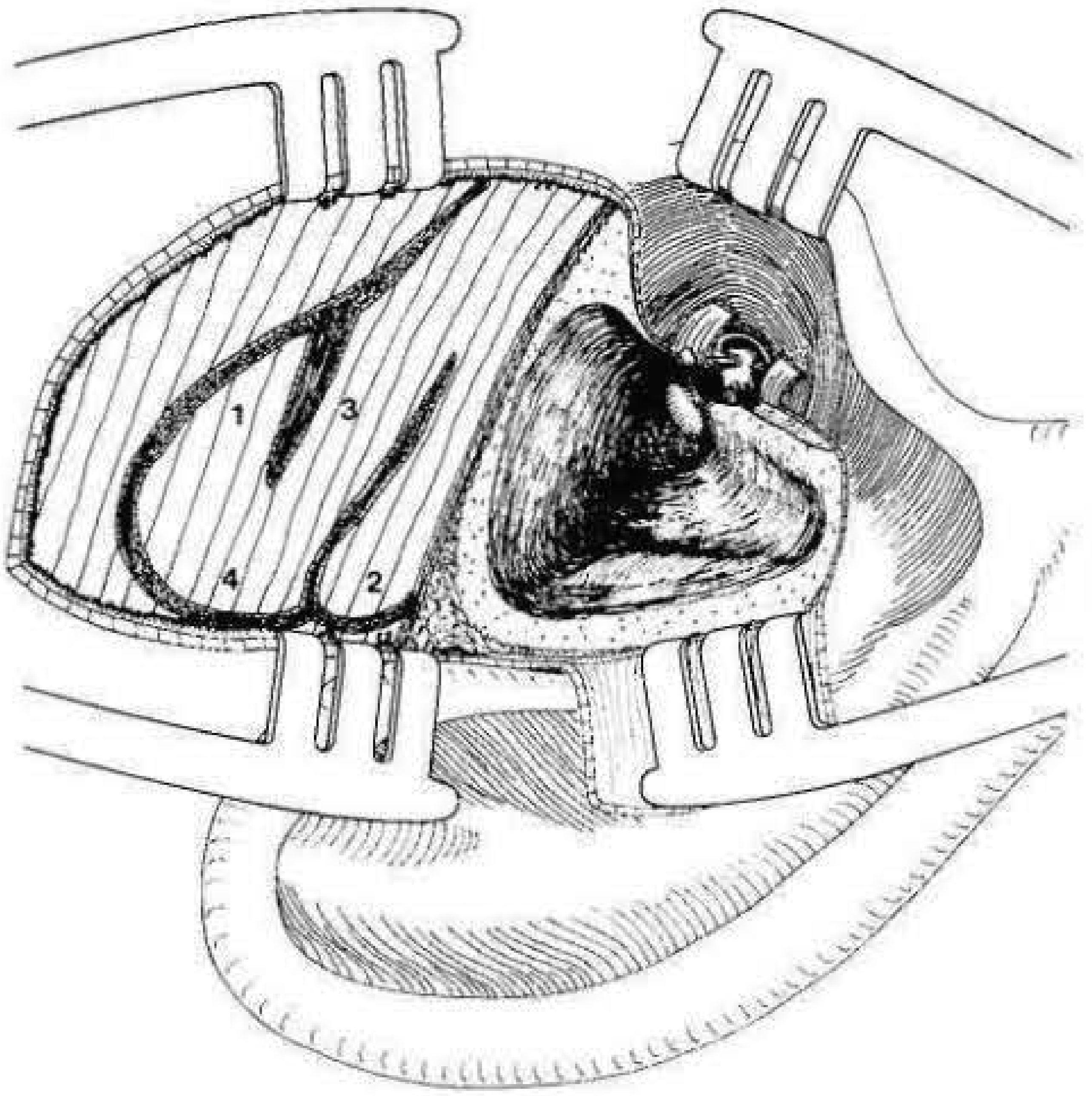


Fig. **914** A conservative radical mastoidectomy is carried out, with removal of the bridge, elevation of superior and inferior canal skin flaps, resection of the malleus head, and extrusion of the incus. Incisions are made through the temporalis fascia and muscle, creating the anteriorly-pedicled tripartite flap (1–4)

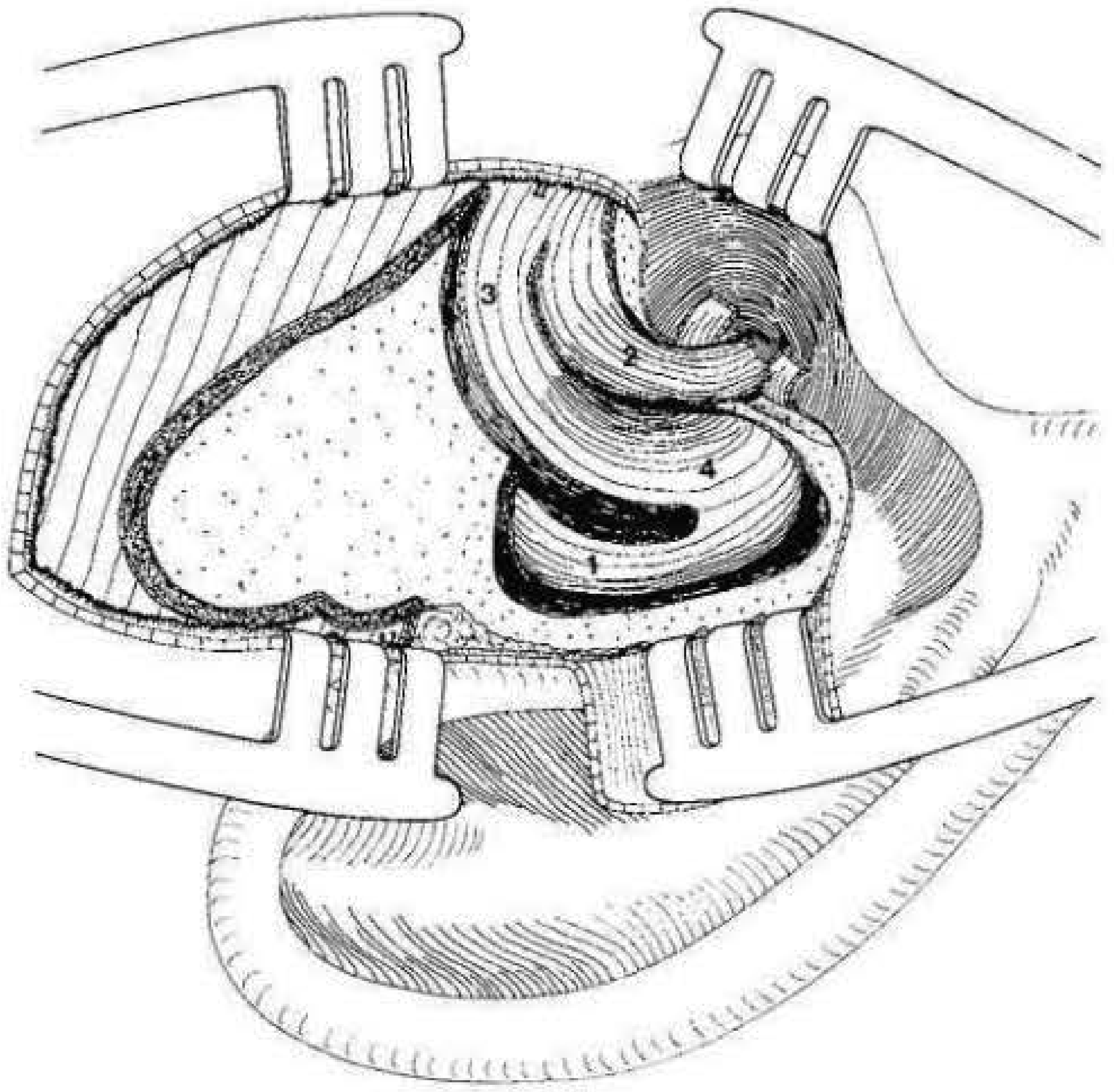


Fig. **915** The smallest flap is placed in the tympanic cavity (2). The largest flap constructs the posterior ear canal wall and obliterates most of the cavity (3, 4). The superior flap (1) obliterates the sinodural angle

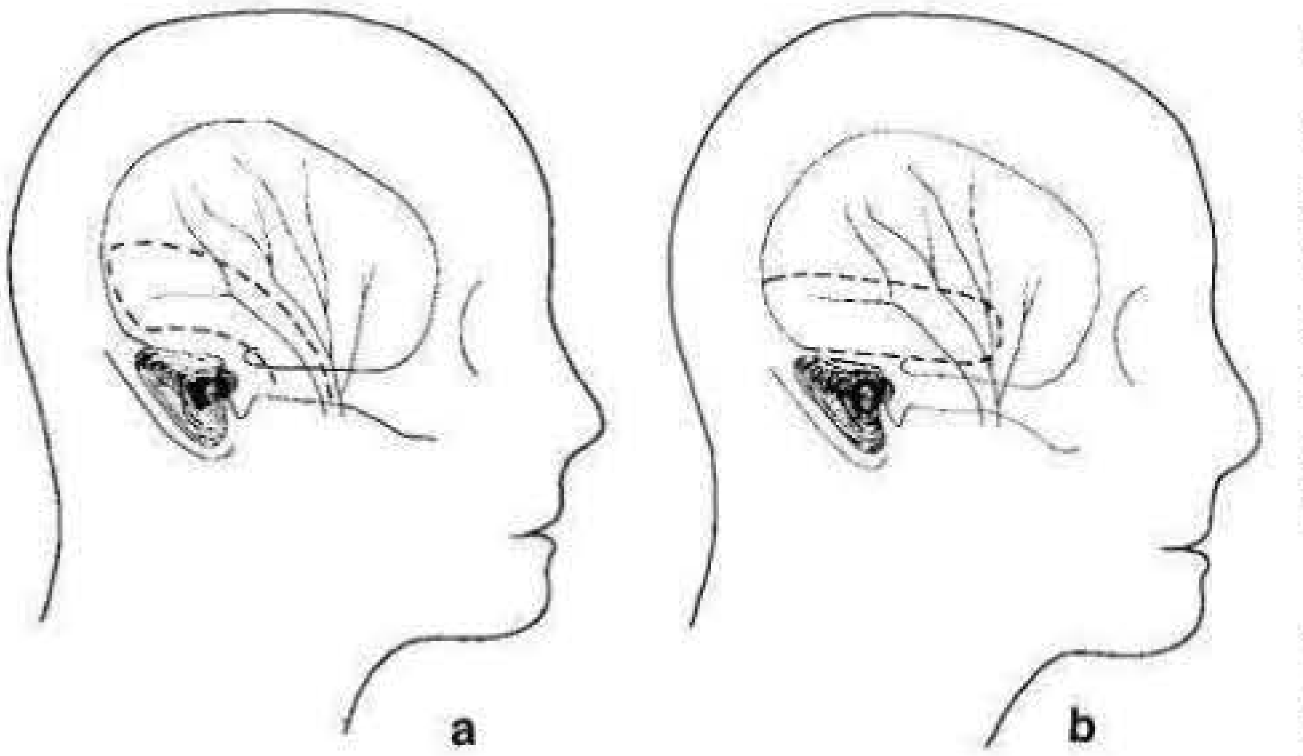


Fig. **916** Experimental temporalis muscle flaps on monkeys, illustrating cutting the nerve fibers at the zygomaticotemporal nerve (Blair Simons et al.). **a** The anteriorly-pedicled flap, with intact innervation. **b** The posteriorly-pedicled flap, with the nerves cut

Atrophy of the Temporalis Muscle

Soon after the introduction of the Rambo (1957) flap, it was pointed out that the muscle became swollen during the first postoperative week, but became smaller by the third postoperative month. Biopsies of the muscle revealed degenerative changes as early as one week after surgery and fibrotic changes three months after surgery (Peck 1961).

Based on a basic law of physiology, the muscle will atrophy if deprived of its nerve supply. The temporalis muscle is innervated by the zygomaticotemporal branch of the zygomatic nerve, which is a branch of the maxillary division of the trigeminal nerve. The zygomatic nerve leaves the trigeminal nerve in the pterygopalatine fossa, and passes through the inferior orbital fissure into the orbit before dividing on its lateral wall into a zygomaticotemporal and a zygomaticofacial branch. The zygomaticotemporal branch leaves the orbit through the zygomaticotemporal canal, entering into the temporal fossa and continuing cranially along the fibers of the temporal muscle before dividing within the muscle and supplying it with nerve fibers (Fig. **916**).

Blair Simmons et al. (1976) demonstrated experimentally on monkeys a complete absence of muscle cells, with their replacement by fibrous tissue, three months after insertion of a posteriorly-based temporalis muscle flap from which the nerve supply has been cut (Fig. **916b**). This was not the case in an anteriorly-based flap with the nerve supply preserved.

In humans, neither anteriorly nor posteriorly based flaps are cut as far anteriorly (Figs. **880, 888, 890, 903–905**) as shown in the animal experiments (Fig. **916**). The only posteriorly based flaps described in humans (Figs. **905, 909**) in fact only include the posterior part of the temporal muscle, far away from the main nerve and arterial supply. In the author's opinion, the arterial supply to the muscle flap is important, and this is poorly preserved in both types of flaps, especially in the posteriorly-based ones. By cutting the muscle flaps anteriorly, the temporal artery and vein are avoided in all methods.

Mastoid obliteration using a large temporoparietal fascia flap, including the superficial temporal artery, is described by East et al. (1991). After a retroauricular incision extended over the temporal region, rather larger than that used by Dawlatly (1992) (Figs. **907, 908**), a large area of temporalis muscle is exposed and incised (Fig. **917**). The incision is made anterior to the course of the superficial temporal artery and vein, which are included in the fascial flap. Fascia is elevated and brought into the cavity, easily covering all walls (Fig. **918**). However, fascia does not obliterate the cavity alone, and this method can hardly be called an obliteration method. In addition, the survival of a large *free* graft of fascia is good.

The same vascularized temporalis fascia flaps, harvested in an endaural approach, has been described as the "Hong Kong" flap (van Hasselt and Liu 1993).

Nevertheless, atrophy and fibrosis of the muscle does occur, and all obliteration methods with muscle will result in some cavity enlargement. It is therefore essential that:

1. The ear canal is considerably widened by cutting through all layers at the 12-o'clock position, as in the Heermann B incision. An incision at the 6-o'clock position is often also necessary, and some methods include excision of the anterior edge of the conchal cartilage.

2. Surgical widening of the ear canal has to be maintained through the postoperative period by continuous packing of the canal, lasting for at least one month, and sometimes for even longer. Postoperatively, practically all widened ear canals have a tendency to become smaller than originally planned, and this is often caused by an inadequate period of postoperative packing of the external auditory meatus.

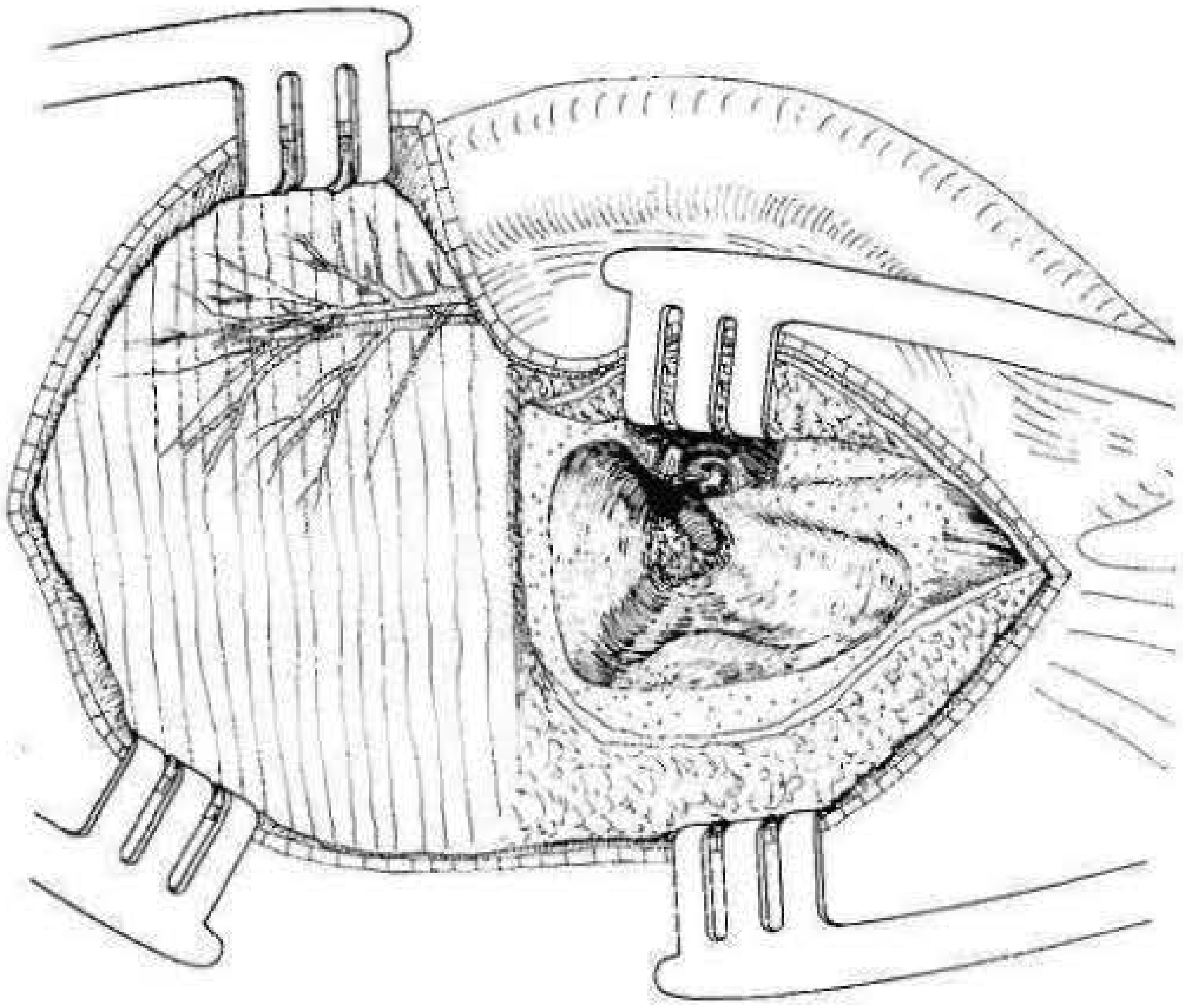


Fig. **917** **Obliteration with fascia and vessels** (East et al.). In a large retroauricular incision, a large area of the temporalis fascia is exposed far anteriorly, exposing the superficial temporal artery and vein with their branches. A conservative radical mastoidectomy is carried out, and superior and inferior tympanomeatal flaps are elevated

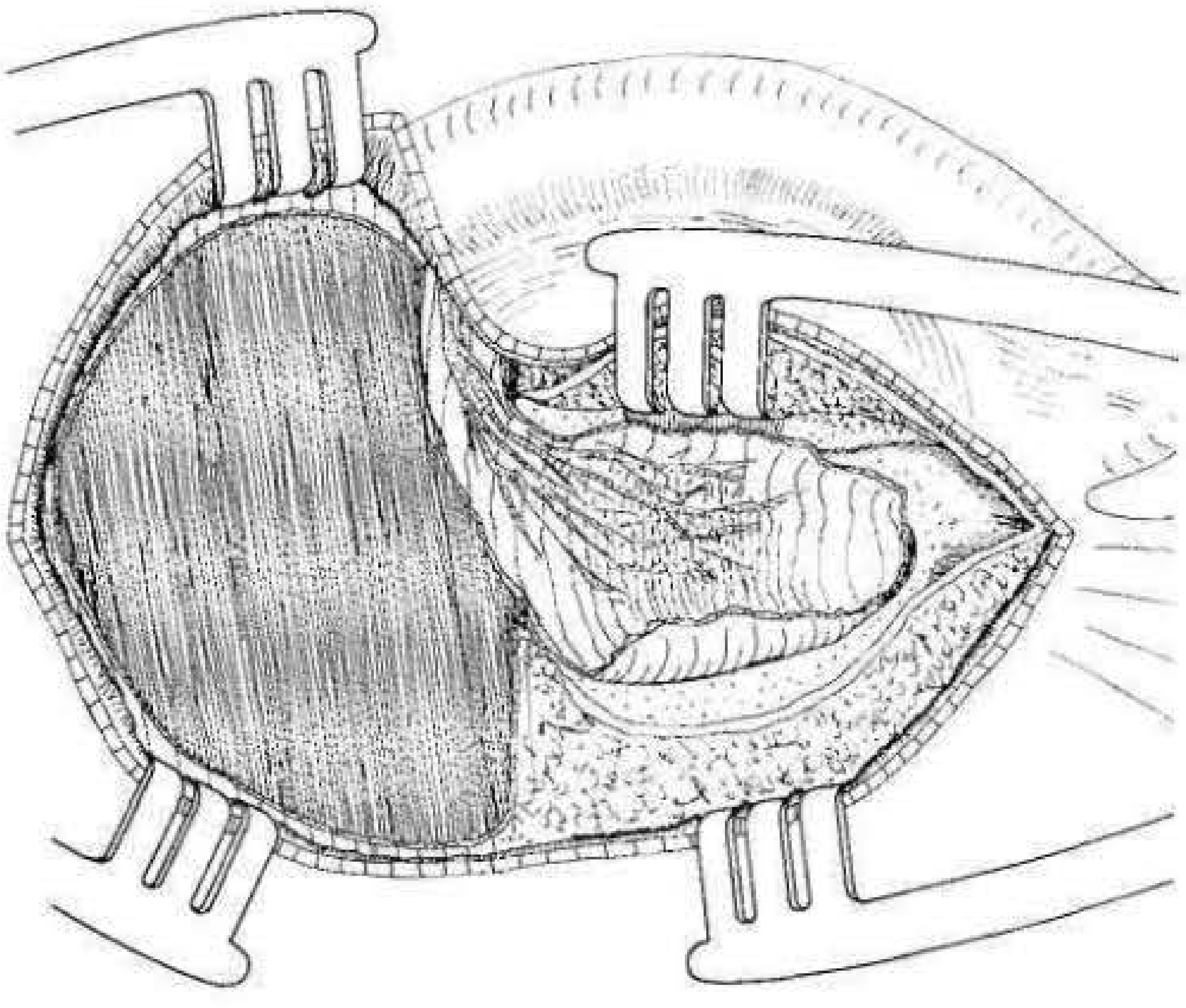


Fig. **918** The temporalis fascia is cut, together with the vessels, forming the anteriorly-pedicled stalk of the fascia. The fascia is brought into the cavity, first covering all the walls and partly obliterating it

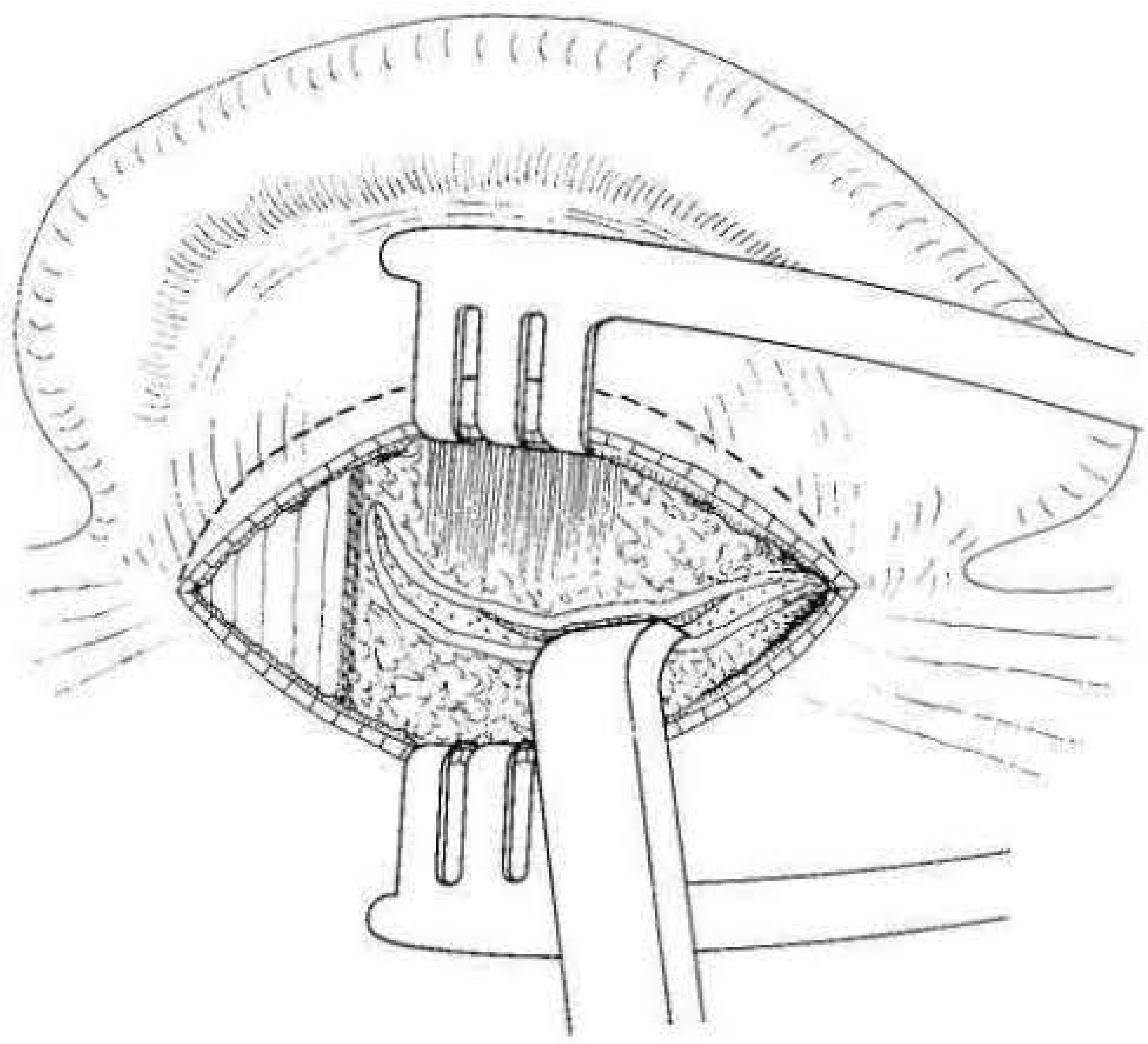


Fig. **919** **The Mosher anterosuperiorly-pedicled conchal tissue flap.** A retroauricular skin incision is made, and an anterior strip of skin is further resected along the dashed line to expose the conchal eminence. A subcutis–periosteum incision is made around the entrance of the ear canal, continuing to the mastoid tip. The subcutaneous tissue and the periosteum are elevated, exposing the mastoid process and the ear canal skin

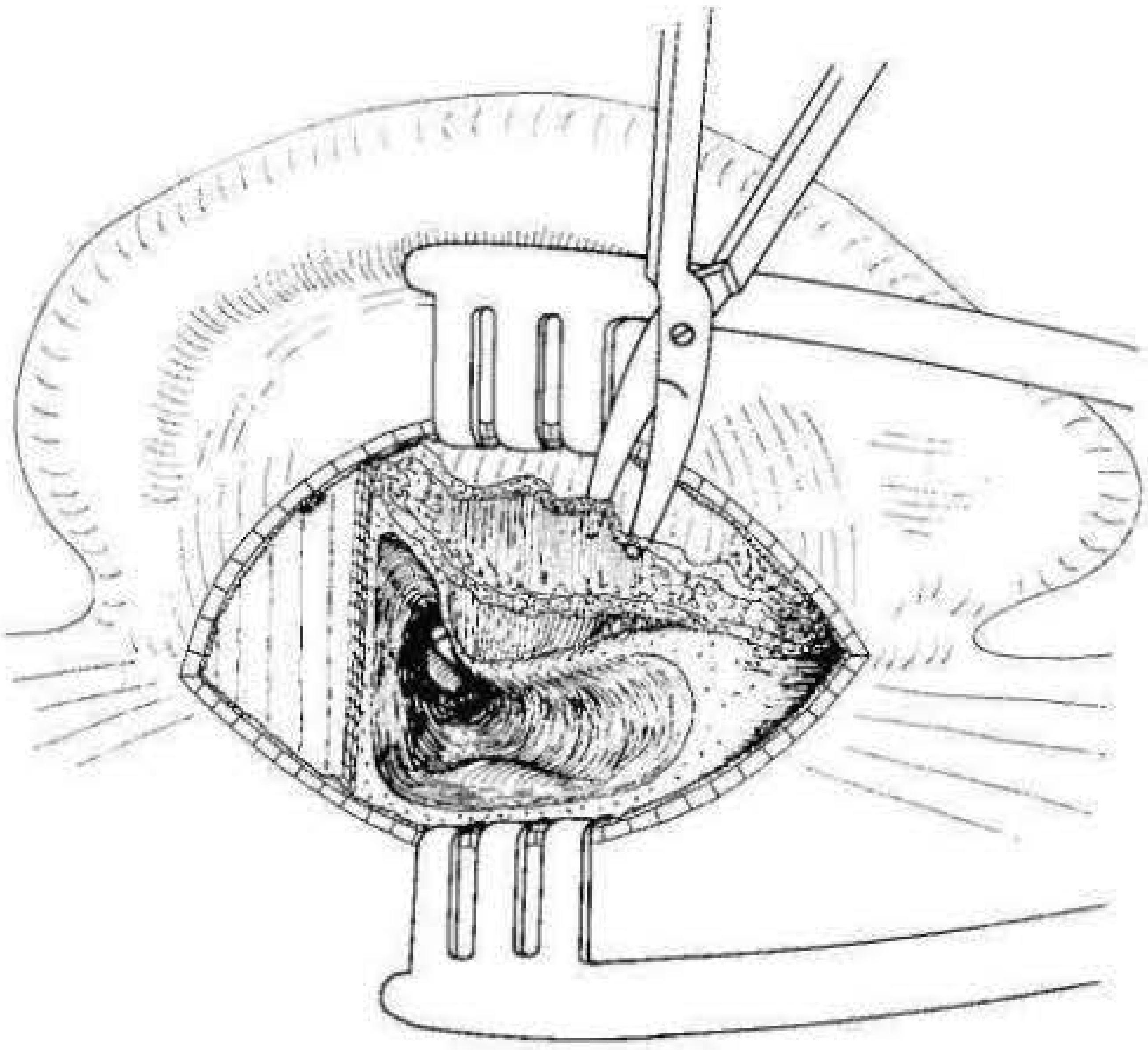


Fig. **920** A simple mastoidectomy is performed, and the posterior bony ear canal wall is removed, except for a small bridge. The anterosuperiorly-pedicled flap is further elaborated by dissecting the tissue, and it covers the conchal eminence down to the mastoid tip

3. The facial ridge should be adequately lowered. The most common postoperative problem encountered when cleaning a cavity with insufficient obliteration is a high facial ridge. This is especially so in cases of obliteration using superiorly based flaps, which often do not reach the inferior part of the cavity.

4. The cavity walls should be polished, especially the mastoid tegmen, antral tegmen, and tympanic tegmen. In case of atrophy, the rebuilt soft ear canal wall will be retracted. In the presence of overhangs and bony irregularities, selfcleaning of the cavity will not be sufficient, and mechanical removal of crusts is often painful.

5. The mastoid air cells should be exenterated and pathological mucosa removed.

6. As a matter of course, cholesteatoma from the mastoid should always be removed.

Anteriorly Based Muscle Flaps

Obliteration with an anteriorly-based muscle graft is the most commonly used obliteration technique today, because the obliteration graft is able, along with the temporalis muscle fascial graft, to simultaneously reconstruct the posterior ear canal wall and completely separate the cavity from the ear canal. This method has been described, promoted, and defended over many years by Palva (1962 a, 1962 b, 1963 a, 1963 b), but there were forerunners of the Palva techniques (Mosher 1911, Popper 1935).

Mosher Flap and Popper Flap

Mosher (1911) was the first to systematically use mesenchymal tissue flaps taken from the back of the auricle and the mastoid process, placing them in the cavity produced by the operation for acute mastoiditis. In fact, this was also the first attempt to reconstruct the bony ear canal using mesenchymal tissue. The flap was used in a special simple mastoidectomy technique employing the removal of the posterior canal wall as in a radical operation, except for a small bridge. Today, this type of operation is called canal wall–down mastoidectomy with an intact bridge.

A retroauricular skin incision and incision through the retroauricular fibrous tissue and periosteum is made. An anterior strip of skin is excised in order to expose the conchal eminence. The flap consisting of fibrous tissue, postauricular muscle, and periosteum is elevated (Fig. **919**), and a simple mastoidectomy with preservation of the bridge is then performed (Fig. **920**). The anterosuperiorly-based flap is further elaborated, dissecting all the tissue covering the concha eminence down as far as the mastoid tip. The fibrous tissue is divided inferioriy and elevated along the conchal eminence. The flap is attached anterosuperiorly to the tissue covering the upper part of the concha (Fig. **921**). It is placed in the cavity to fill the bony defect after removal of the posterior ear canal wall and to obliterate the cavity.

The present author and all otosurgeons using the Palva obliteration technique and other obliteration and reconstruction methods employing a retroauricular approach, as well as those using the conchal perichondrium and cartilage in reconstruction. have used the Mosher technique in order to harvest some mesenchymal tissue anteriorly as an additional flap for reconstruction of the ear canal. It is fascinating to see how precisely and meticulously these methods were described by Mosher in 1911. The only difference from the methods used today is that Mosher cut the flap medially from the concha and the ear canal, leaving it only pedicled anterosuperiorly (Figs. **921, 922**).

The Popper flap (1935) is created using a similar retroauricular approach, including mainly the retroauricular periosteum, with some fibrous tissue. The flap is cut rectangularly and is broadly based anteriorly, similar to, but smaller than, the Palva flap (Fig. **923**). This flap is mainly a periosteal flap.

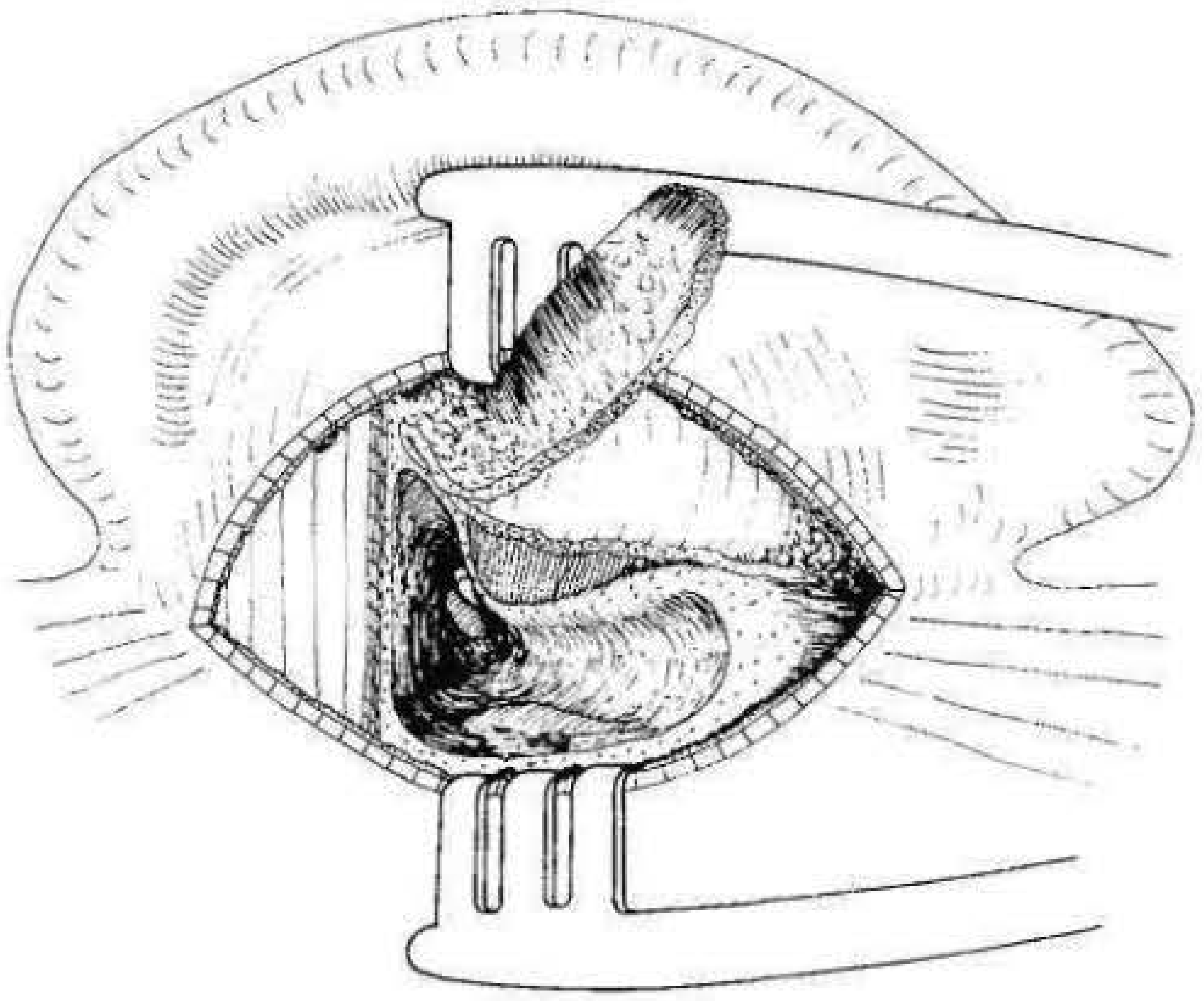


Fig. **921** After the subcutaneous and fibrous tissue have been cut inferioriy, the flap is elevated. It is anterosuperiorly pedicled

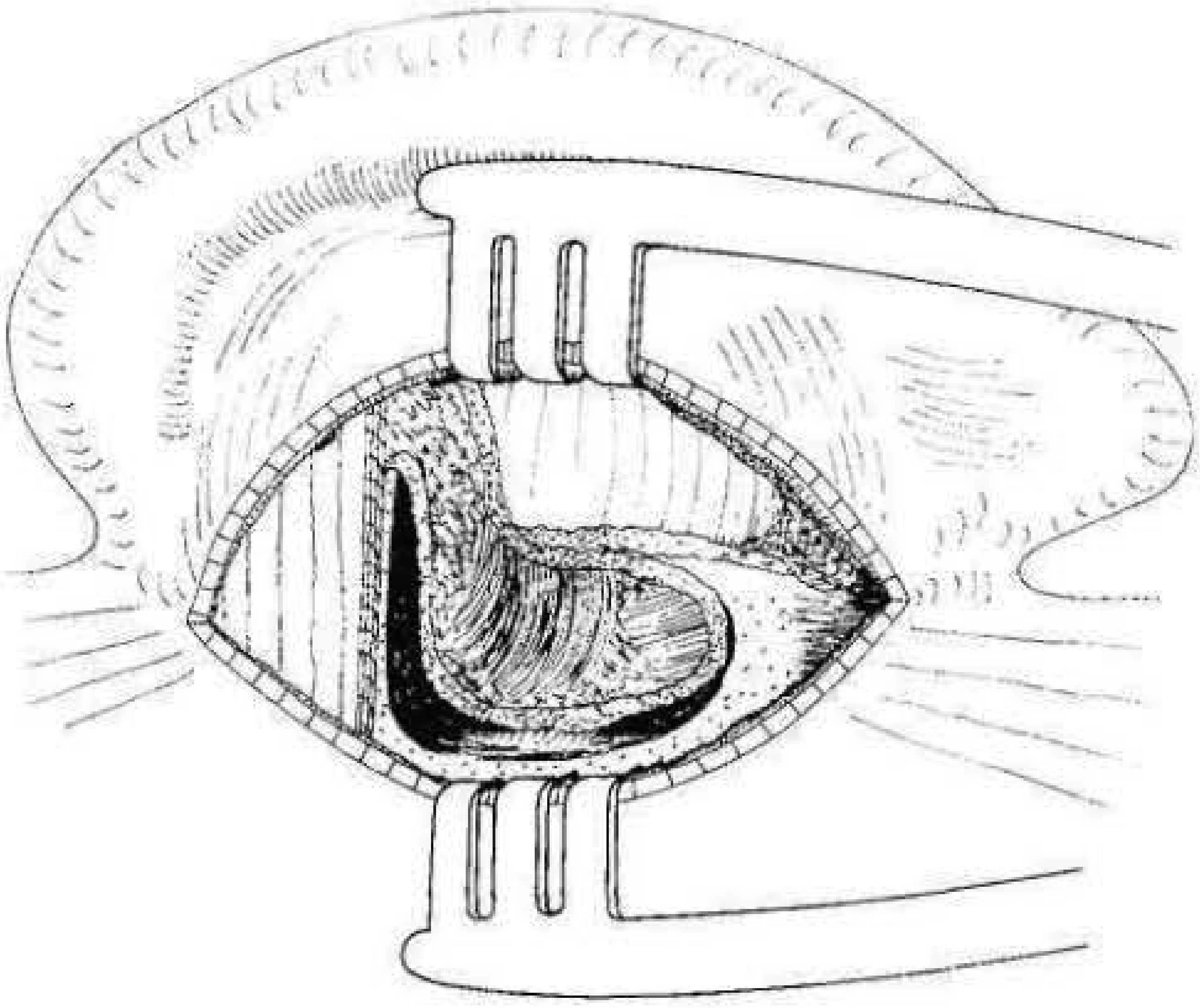


Fig. **922** The flap is placed in the cavity, covering the defect in the posterior ear canal and obliterating part of the cavity

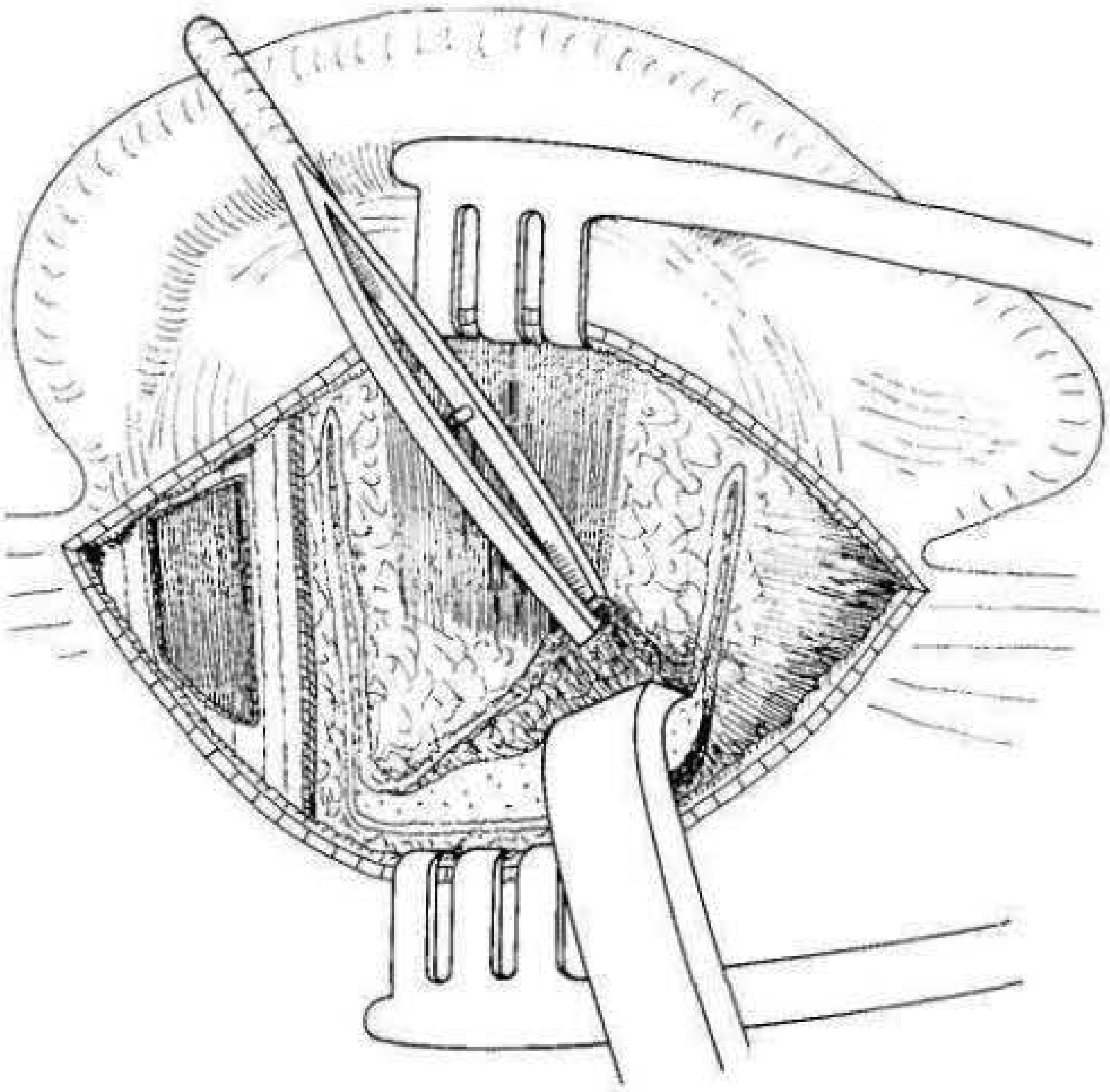


Fig. **923** **Reconstruction of the ear canal and obliteration of the cavity with Palva flap.** After a retroauricular skin incision and harvesting of the temporalis muscle fascia, a rectangular incision through the musculoperiosteal tissue on the surface of the mastoid process is made, and a 2×3 cm–long flap elevated

The Palva Flap

If any ear surgeon deserves to have his name connected to a specific method then this must be Palva, who has consistently carried out obliteration of the mastoid cavity and reconstruction of the ear canal since 1957. Even Palva himself, in his first publication on the obliteration technique (Palva 1962a), observed that "it has been my practice for many years to reinforce the separation of the cavity from the middle ear by creating a postauricular musculoperiosteal flap, originally described by Popper in 1935." The term "Palva flap" is currently used worldwide to describe the anteriorly-based flap. In many well-documented papers, Palva proved the long-term validity of the concept of cavity obliteration (Palva 1962 b, Palva, 1963 a, 1969 b, Palva et al. 1970, Palva and Mäkinen 1979).

After a retroauricular incision 1–3 cm posterior to the sulcus, the posterior wound margin is undermined for about 3 cm. The ear canal is identified, and a rectangular piece of musculoperiosteal tissue on the surface of the mastoid process at least 2 cm wide and 3 cm longis incised and elevated (Fig. **923**). This flap size is suitable for small cavities, and Palva pointed out as early as 1963 that the flap can have almost any size, depending upon the extent of mastoid pneumatization.

The flap is left attached laterally to the posterior ear canal wall, and the ear canal skin is elevated (Fig. **924**). The canal wall–down mastoidectomy is performed, the canal skin flaps are elevated, and all pathology from the tympanic cavity and mastoid process is removed (Fig. **925**).

Myringoplasty and ossiculoplasty are performed (Figs. **926, 927**), with a large piece of fascia placed under the drum, and the tympanomeatal flaps are repositioned. The meatal side of the fascia is covered with the skin flaps. The ear canal is packed with Gelfoam, and the muscle is then turned into the cavity. If it is too short it can be cut with a pair of scissors along the conchal eminence (Fig. **928**). The flap is then turned down into the cavity (Fig. **929**).

To avoid the soft ear canal wall collapsing, Palva recommends a firm tamponade of the ear canal, e. g., using Merocel or gauze medially, instead of Gelfoam.

Palva initially used pieces of Gelfoam behind the flap to fill out the cavity (Fig. **930**). After widening and packing of the ear canal, the flap is pushed posteriorly (Fig. **931**).

The Palva flap is a good flap for reconstruction of the ear canal, but the posterior part of the cavity and the mastoid tip are not obliterated, and they either have to be filled with some other material, or the ear canal has to be maximally widened.

Although the Palva flap is broad-based and well vascularized, the muscle fibers from the postauricular muscle may eventually become atrophic, and precautions to avoid a narrow ear canal or a large non-selfcleaning cavity, or both, therefore

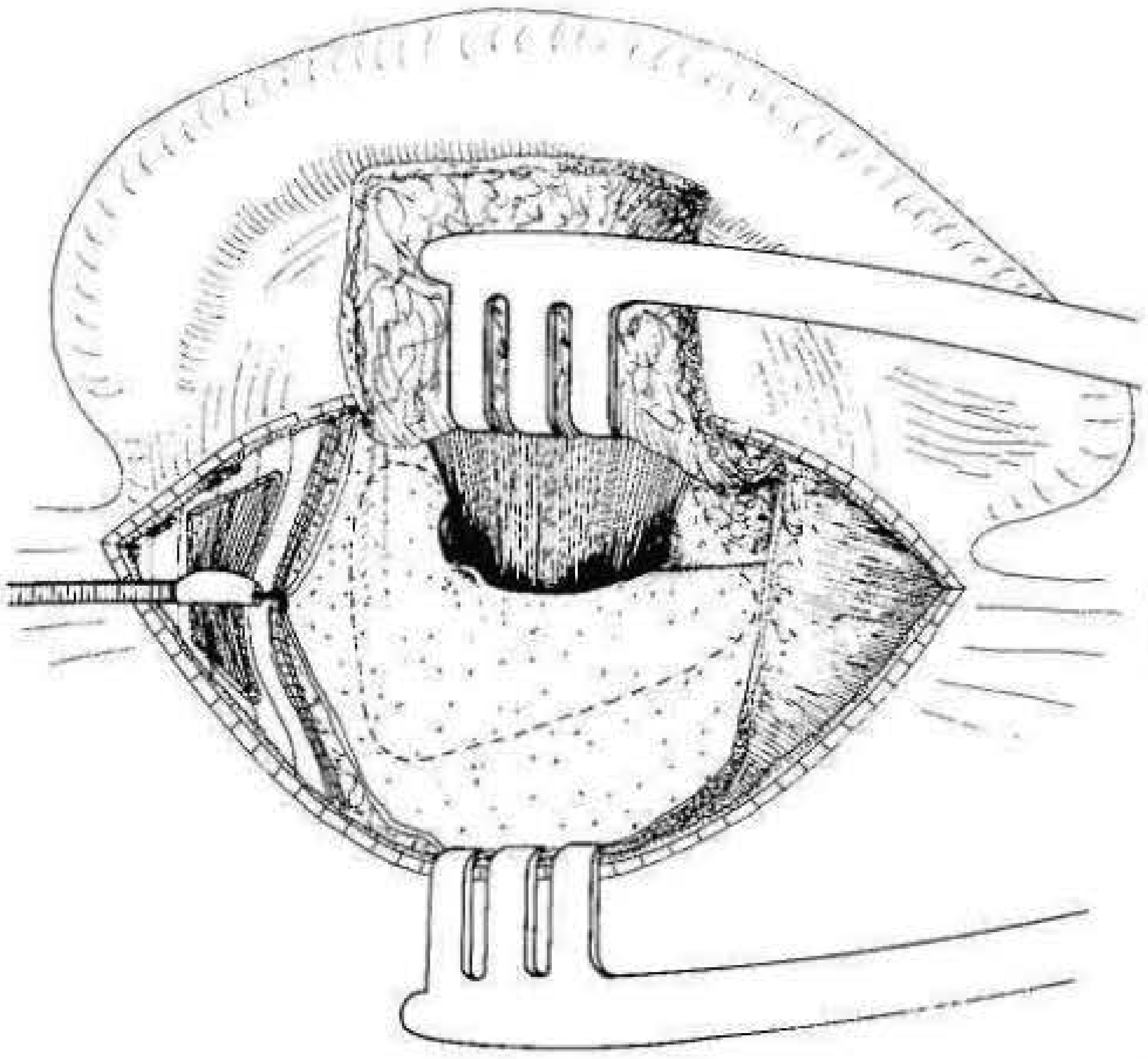


Fig. **924** The Palva flap is held under the anterior blade of the selfretaining retractor. The mastoid surface is exposed, and the canal skin is elevated

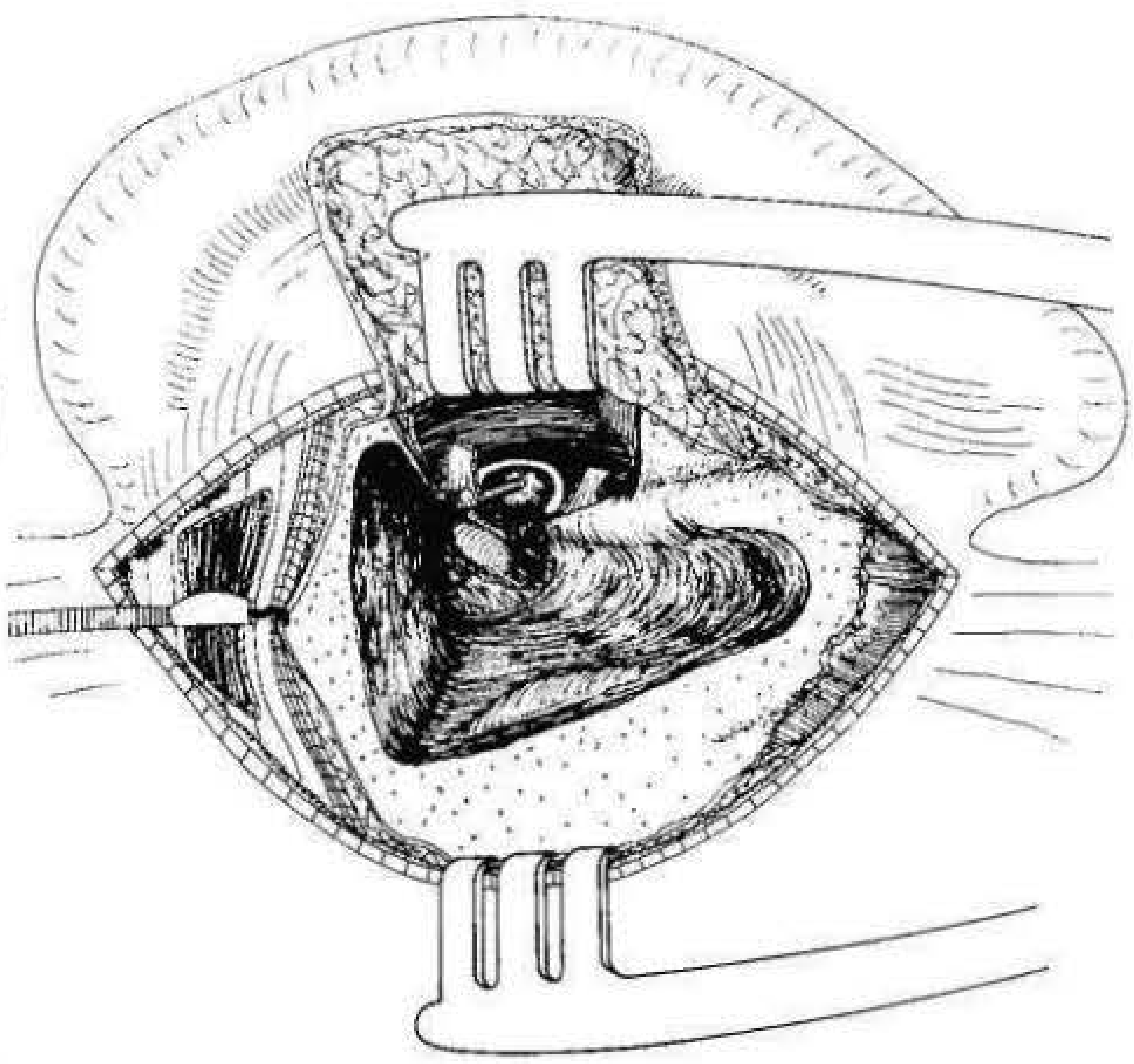


Fig. **925** A canal wall–down mastoidectomy is carried out, and a superior and inferior canal skin flap are elevated. The tympanic cavity is exposed

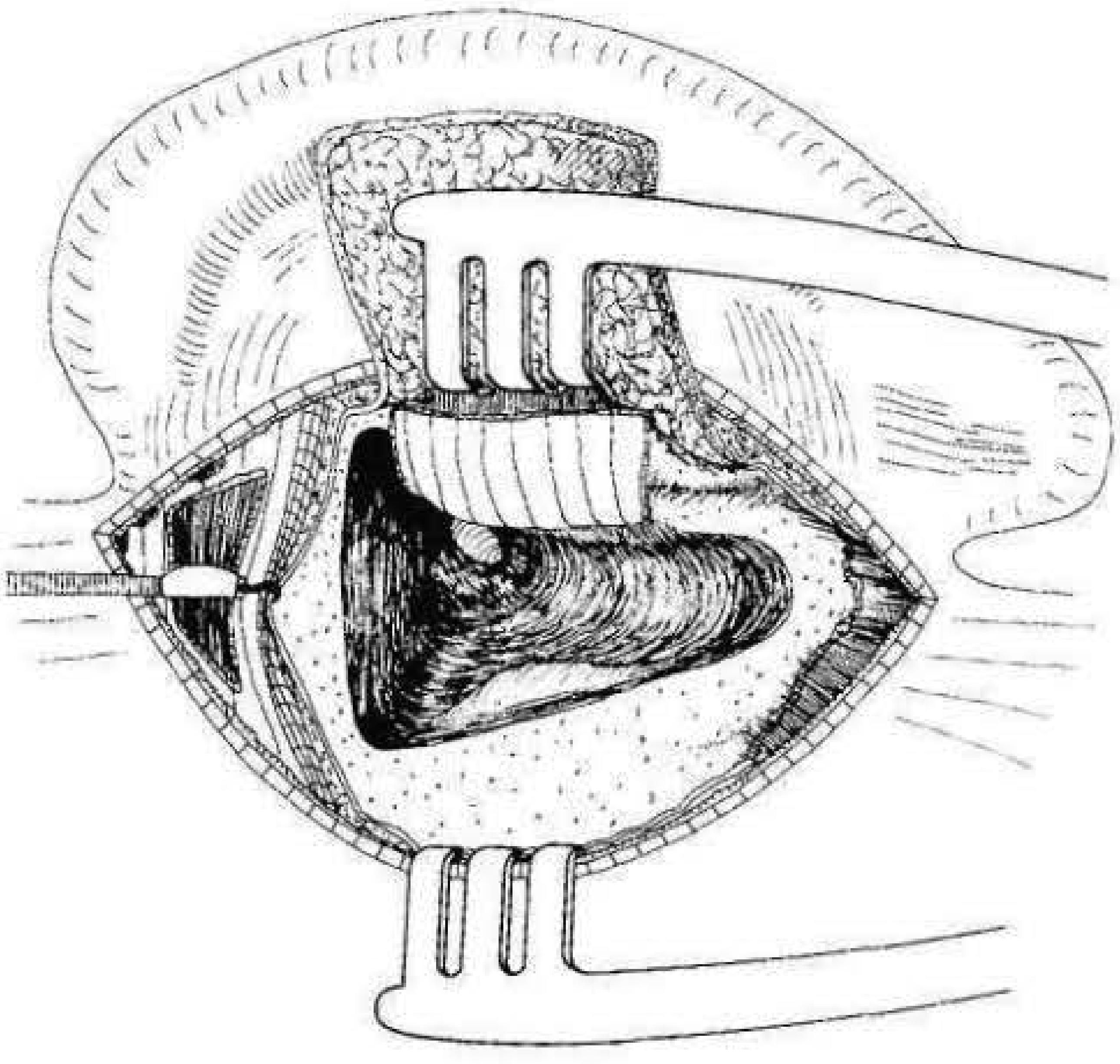


Fig. **926** After an ossiculoplasty and closure of the perforation, the fascia is turned around the ear canal skin The meatal side of the fascia is covered with the skin flaps

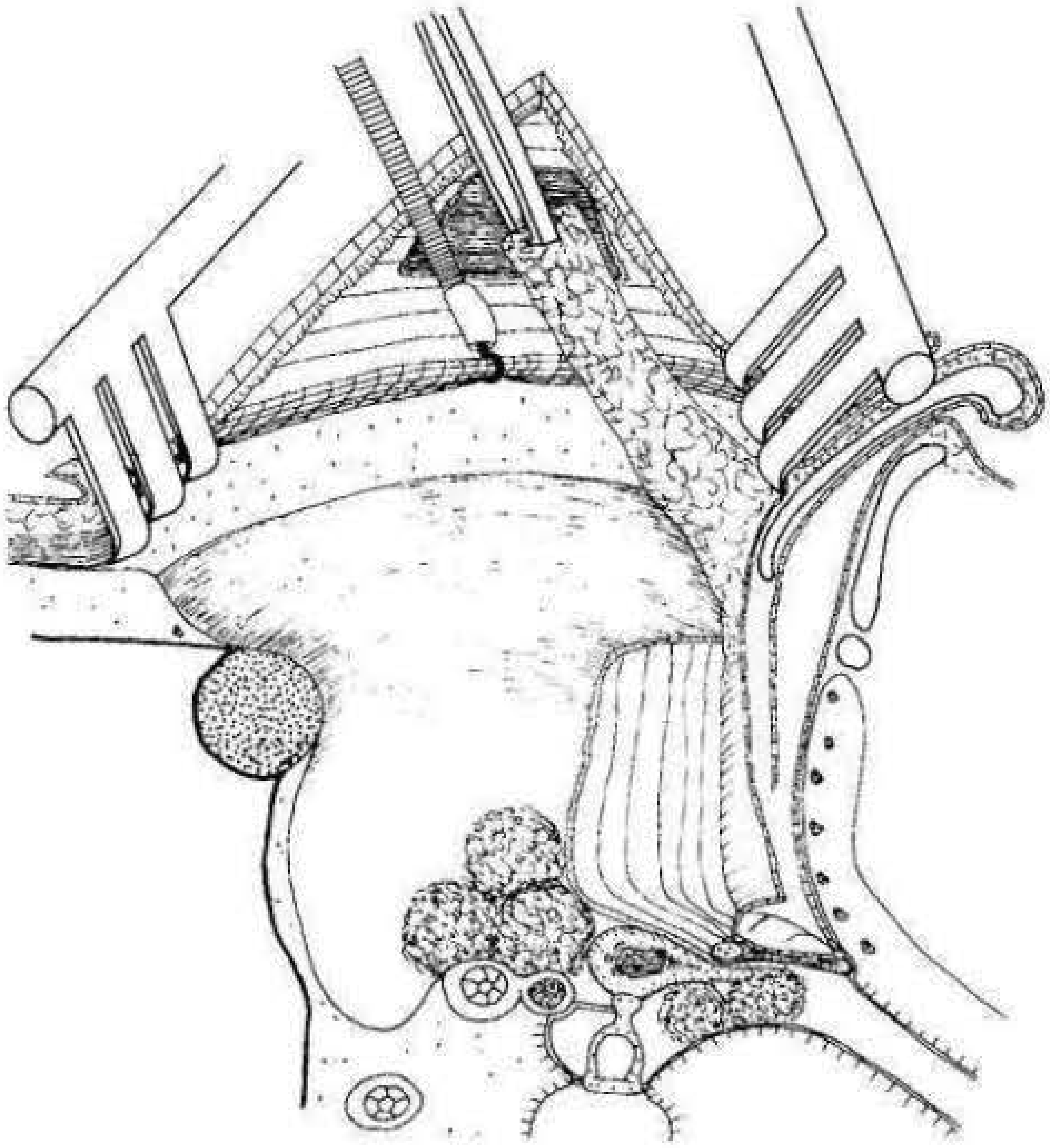


Fig. **927** Side view with some perspective, illustrating the type-2 tympanoplasty with an incus and a piece of fascia placed under the malleus, turning laterally at the level of the bridge to cover the posterior aspect of the ear canal. The sections, through the superior and lateral semicircular canals and through the facial nerve are indicated. The posterior thick line indicates the dura and the dotted round area indicates the sigmoid sinus

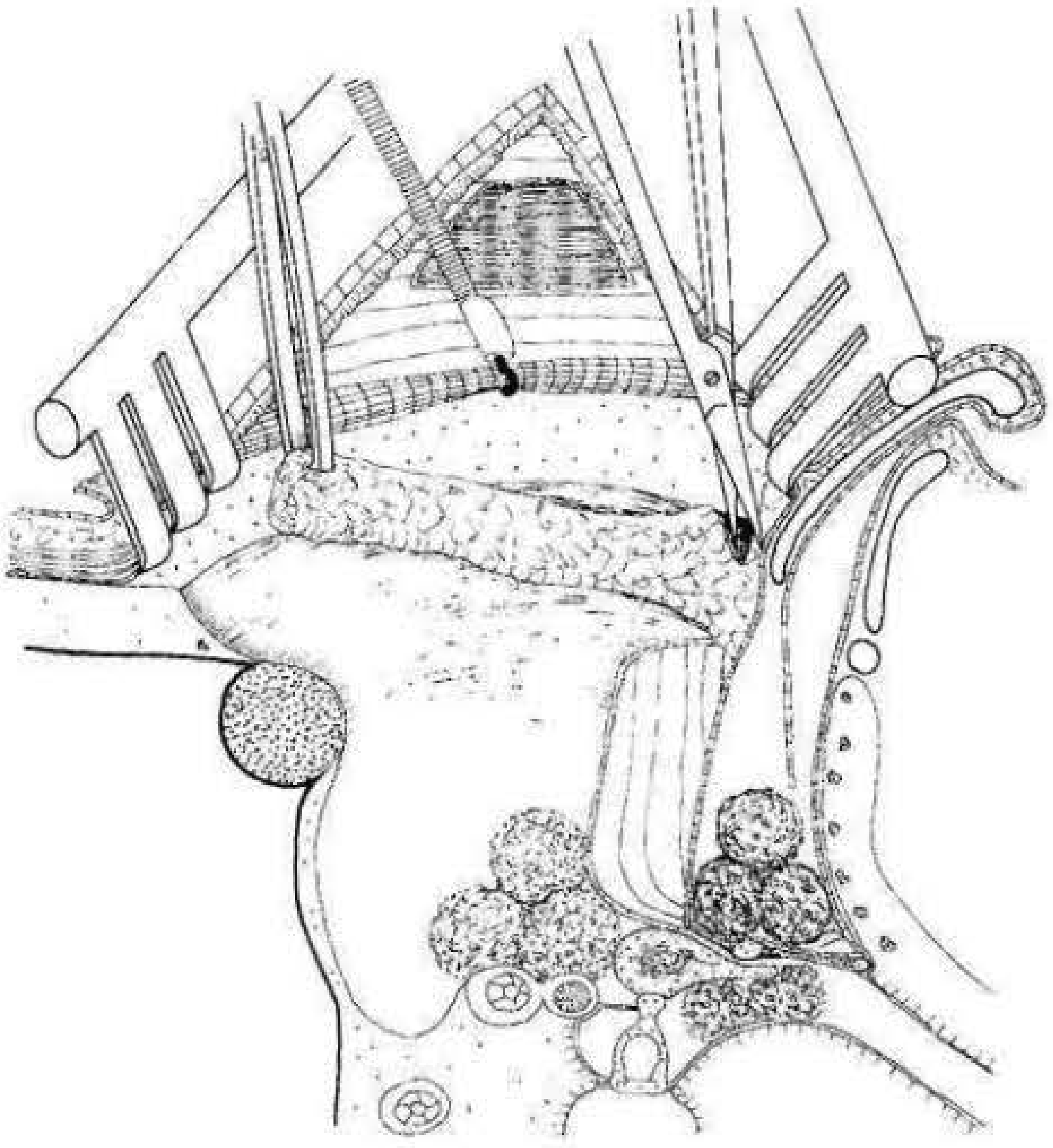


Fig. **928** The tympanomeatal flaps are replaced. The Palva flap is turned down into the cavity. If necessary, the Palva flap can be elongated by cutting it along the conchal eminence with a pair of scissors

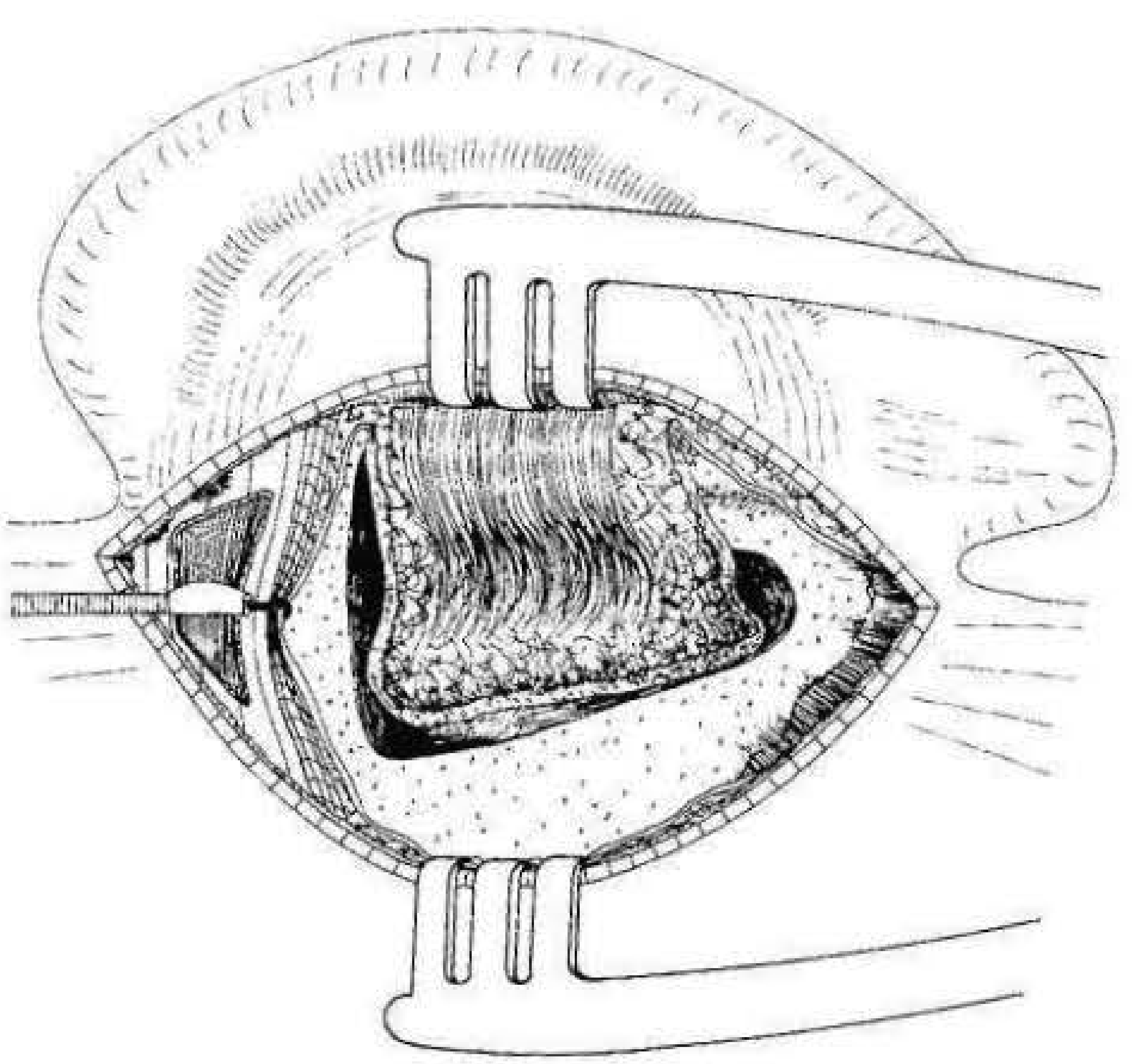


Fig. **929** The Palva flap is placed in the cavity, reconstructing the ear canal wall and partly obliterating the cavity

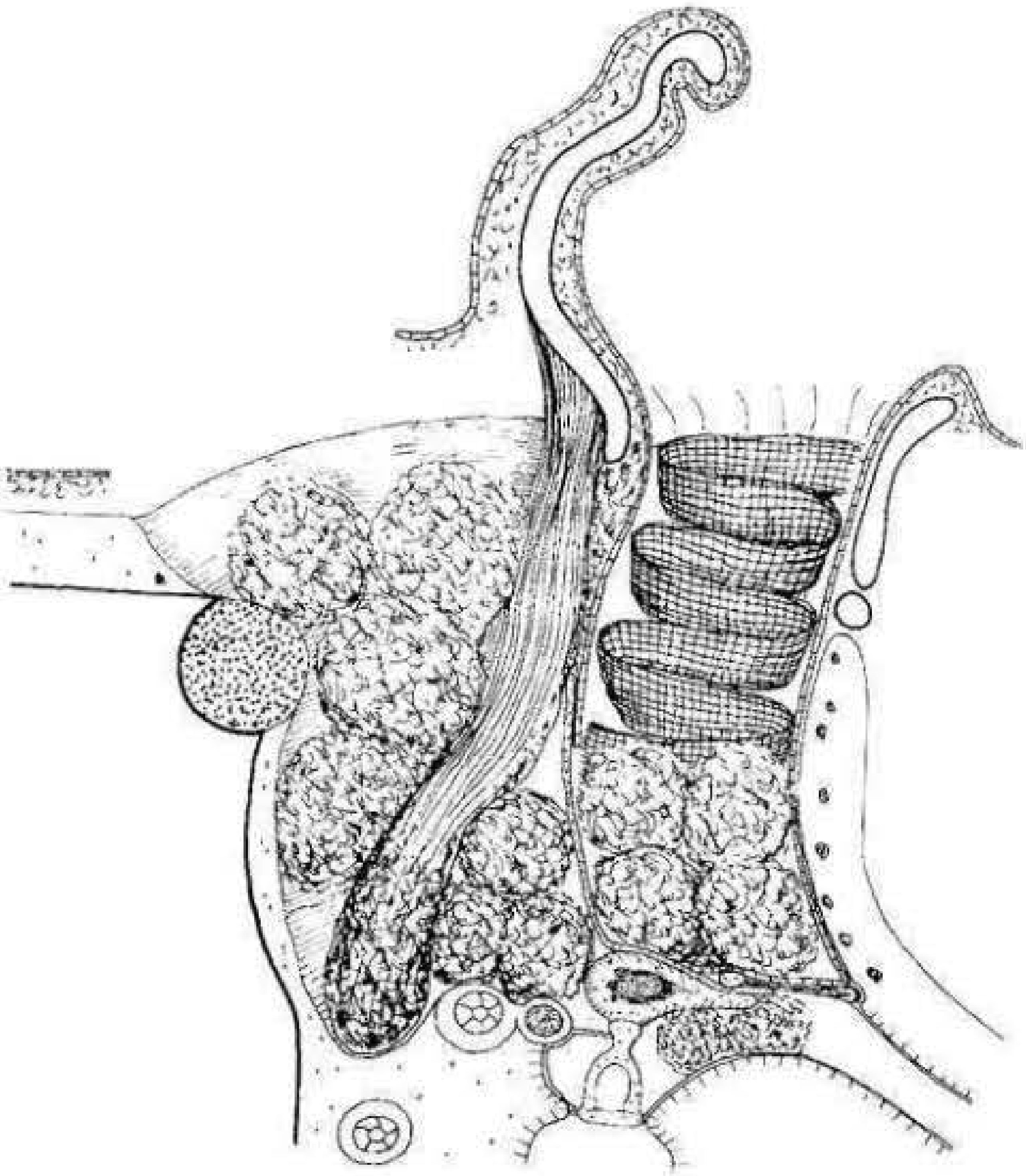


Fig. **930** **Side view of the Palva flap in place, reconstructing the ear canal.** The fascia lies on top of the Palva flap and underneath the skin flap. The ear canal is packed with Gelfoam balls, and a 1 cm–broad piece of gauze moistened with oxytetracycline and hydrocortisone (Terra-Cortril) ointment. Some Gelfoam balls are placed in the attic, supporting the fascia. Behind the Palva flap, Gelfoam balls obliterate the rest of the cavity

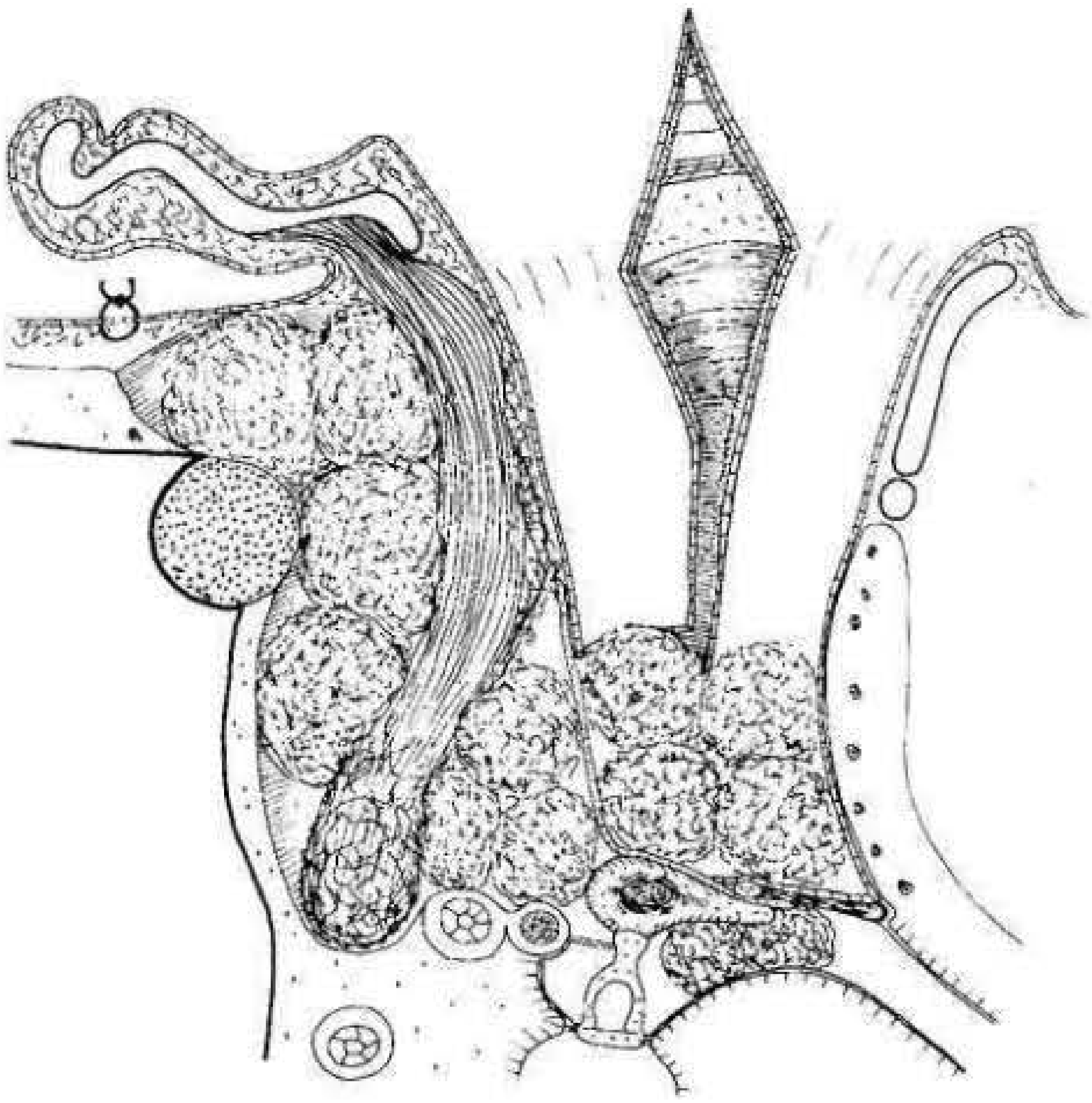


Fig. **931** The ear canal is widened maximally using a Heermann B–like incision at the 12-o'clock position, cutting through all the layers down to the bone. The incision extends through the entire ear canal. The widening of the ear canal allows the Palva flap to be pushed far posteriorly, compressing the Gelfoam balls. The ear canal will be packed with gauze

have to be employed in the same way as for the anteriorly-based flap and the superiorly-based flap. These are:

1. Widening of the ear canal.
2. Maintaining the widened ear canal postoperatively.
3. Lowering the facial ridge.
4. Polishing the cavity walls.
5. Exenteration of all mastoid cells and pathological mucosa, as well as other pathology, especially cholesteatoma.

Enlargement of the Palva Flap

If necessary, the Palva flap can be considerably enlarged to include the temporalis muscle, attached superiorly, and the splenius capitis muscles and transversus nuchae muscle inferiorly.

The author uses the following method for enlargement of the Palva flap, although, the use of a larger flap has to be predicted. A large, curved, retroauricular incision 4–5 cm behind the retroauricular fold, similar to that used in the translabyrinthine approach, is made. The skin is undermined, elevated, and held in place with selfretaining retractors (Fig. **932**). Superiorly, an incision is made through the fascia and the temporalis muscle, including 1 cm of the temporalis muscle with the fascia is the flap. Posteriorly, the incision goes through the temporalis muscle, relatively thick fibrous tissue, the splenius capitis muscle, and the transversus nuchae muscle, as well as the longissimus capitis muscle. Inferiorly, the flap includes fibers of the sternocleidomastoid muscle. This relatively thick flap is elevated far anteriorly, exposing the ear canal skin (Fig. **933**). The ear canal incisions are then performed, creating an inferior and a superior tympanomeatal flap. After a canal wall–down mastoidectomy (Fig. **934**), the reconstruction is performed. After ossiculoplasty, a large fascia flap is placed under the drum remnant, and the tympanomeatal flaps are replaced (Fig. **935**). The superior and inferior parts of the Palva flap are incised as far as its base, resulting in three flaps. Before turning back these flaps, the ear

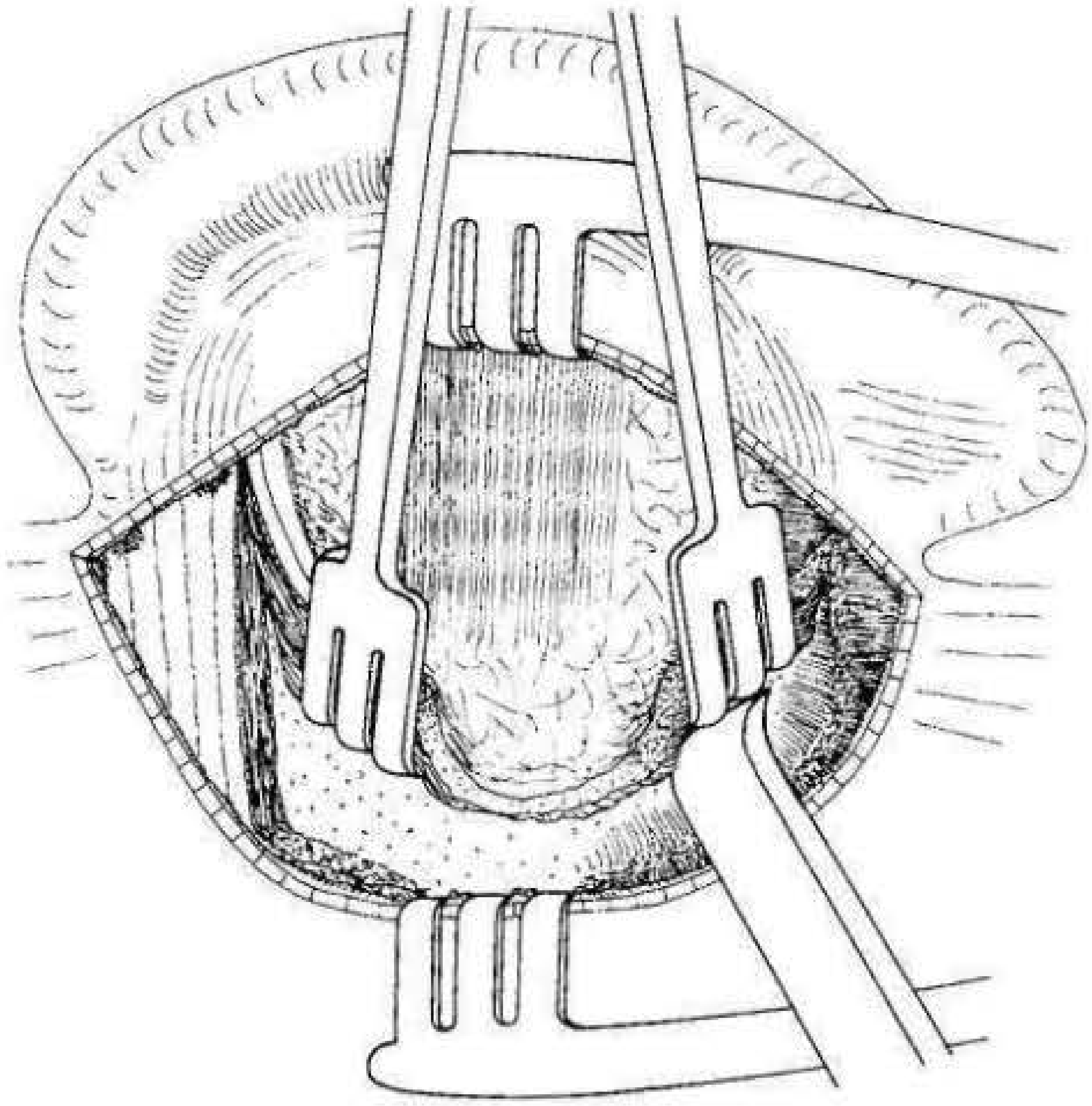


Fig. **932** **Enlargement of the Palva flap.** A large, curved, retroauricular skin incision is made 4–5 cm behind the retroauricular fold. The skin is elevated far anteriorly. The temporalis fascia and temporalis muscle are incised 1 cm superior to the margin of the temporalis muscle. The posterior incision goes through the fibrous tissue and muscles, continuing inferiorly to the mastoid tip, where it is turned anteriorly

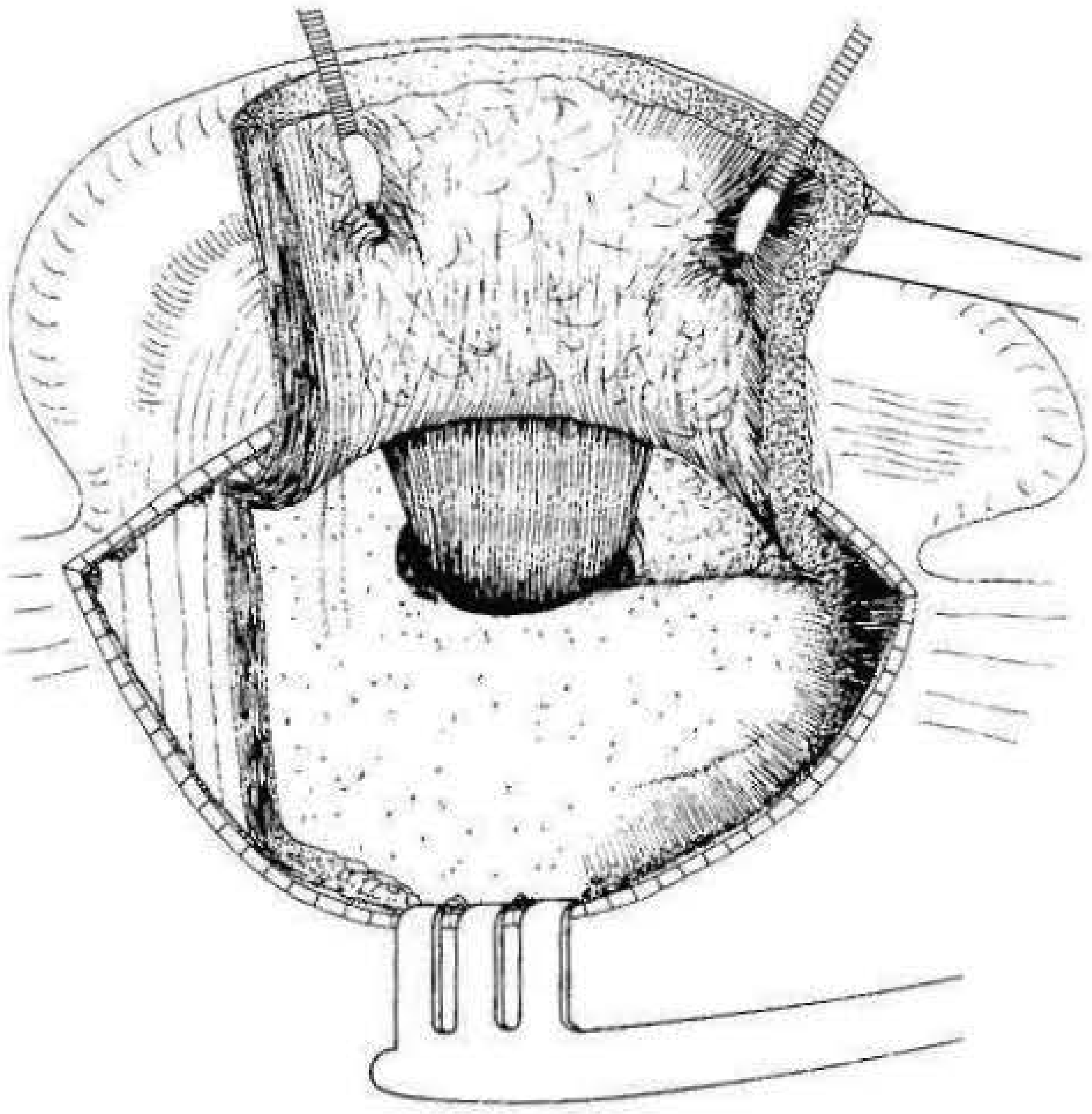


Fig. **933** A large Palva flap is elevated anteriorly, exposing the ear canal skin. It is held in place by surgical stays

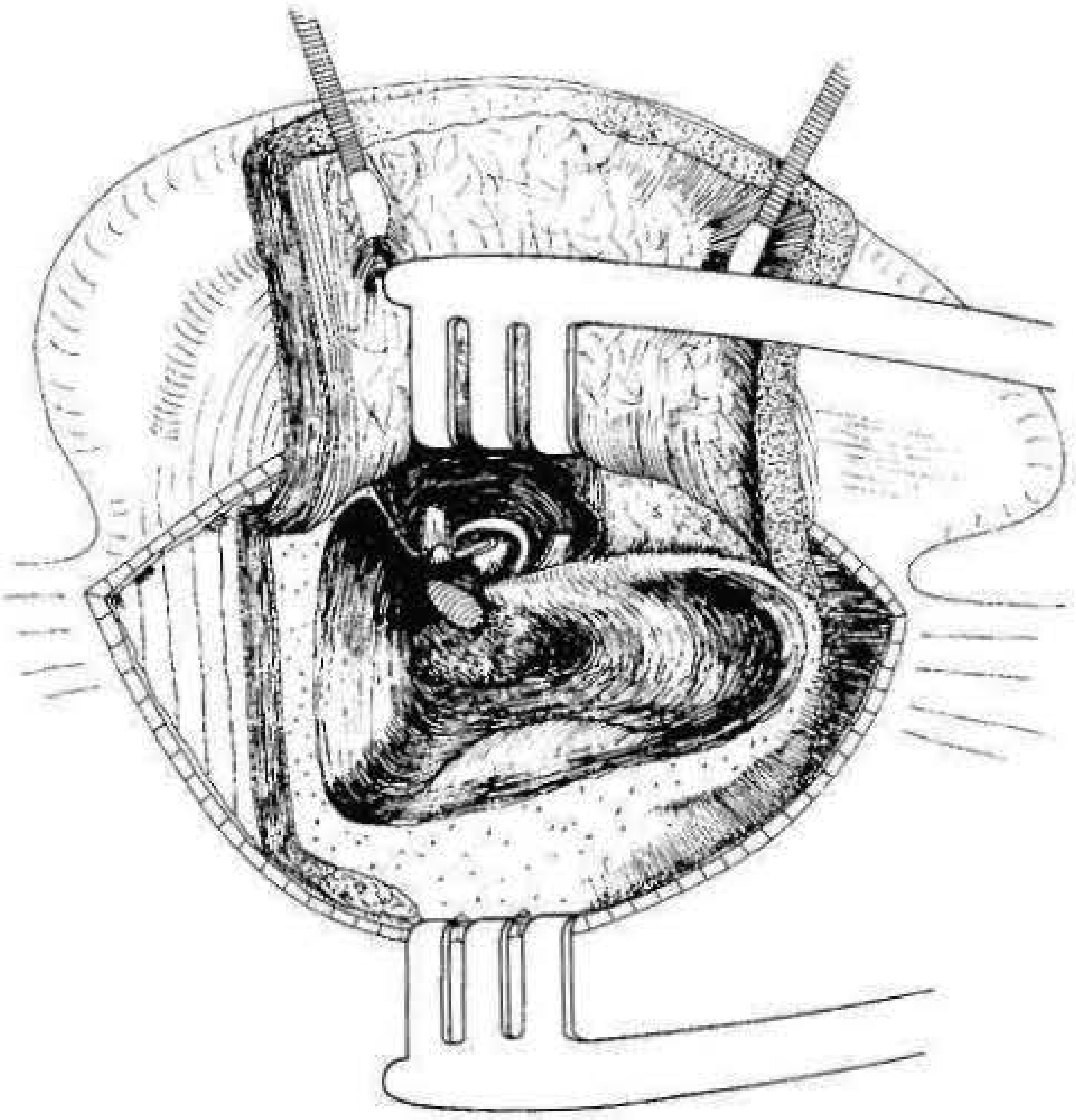


Fig. **934** A canal wall–down mastoidectomy is carried out, and the inferior and superior ear canal skin flaps are elevated, exposing the tympanic cavity

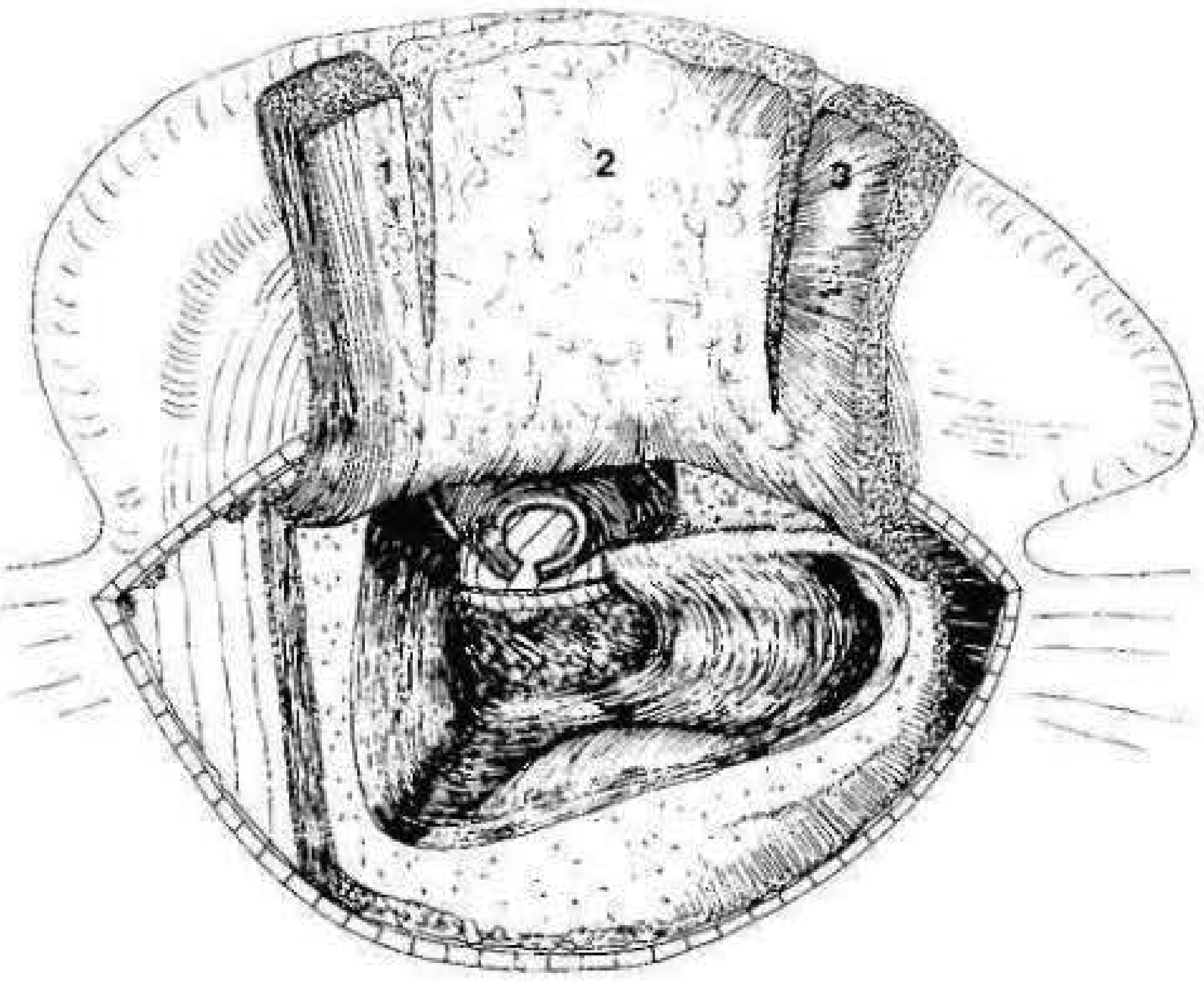


Fig. **935** A large piece of fascia is placed under the drum, the canal skin flaps are replaced, and the fascia is elevated laterally and anteriorly toward the muscle flap. The superior and inferior parts of the flaps are incised as far as its base, resulting in three flaps (1, 2, 3). It is important during the procedure of cutting the muscle flaps to place a strip of dry gauze in the cavity in order to prevent blood filling the cavity and ear canal, avoiding the suction around the fascial graft

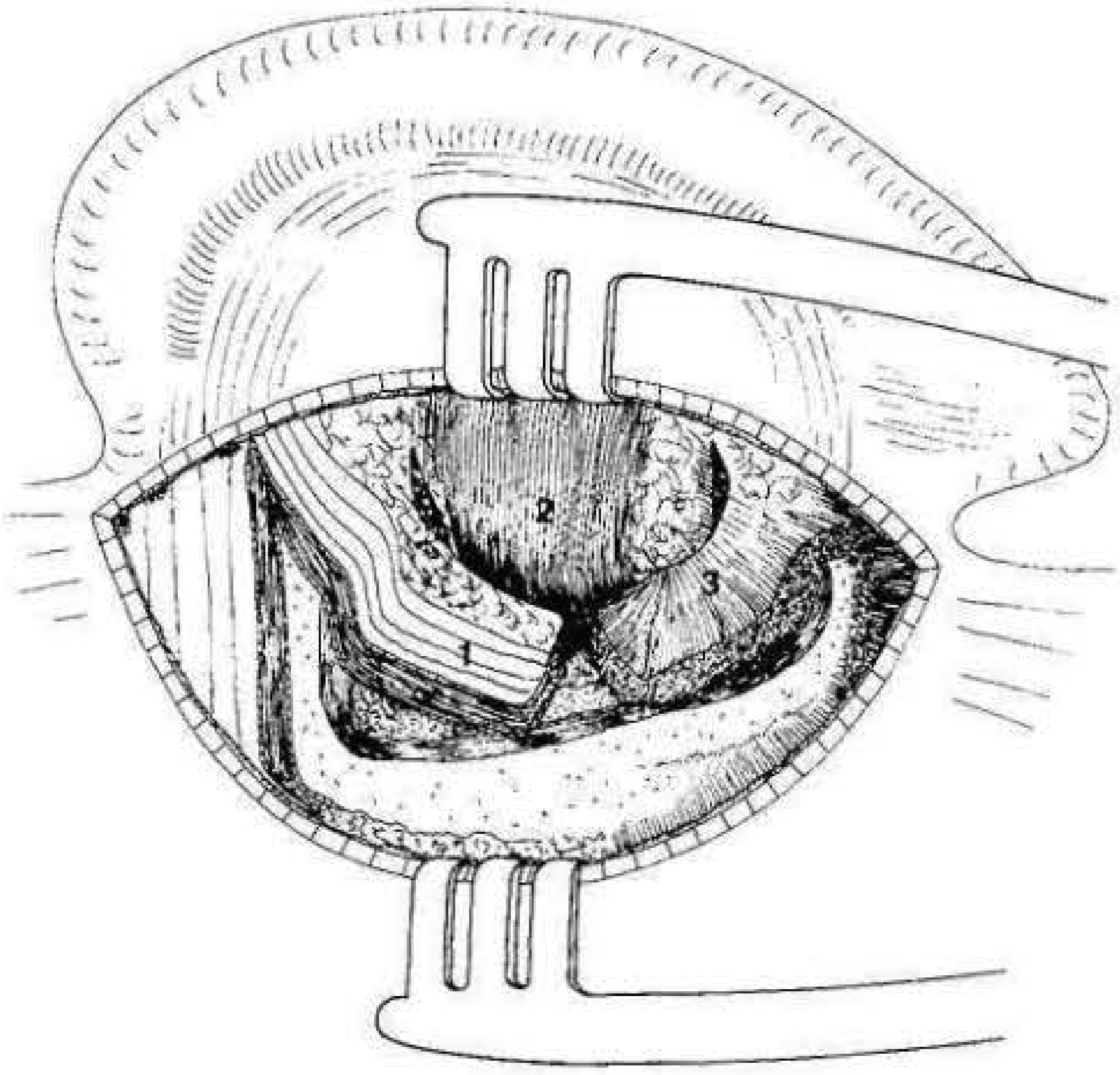


Fig. **936** Immediately after removal of the gauze, the large Palva flap is turned into the cavity (2), obliterating the anterior part of the cavity and reconstructing the ear canal. The smaller superior flap (1) obliterates the superoposterior part of the cavity. The inferior flap (3) obliterates the inferior part of the cavity

canal is packed with Gelfoam, and the fascia is turned laterally and anteriorly to the Palva flap in order to close the ear canal in the same way as illustrated in Figures **926–928**. The broadest flap obliterates the anterior part of the cavity, thus forming the ear canal wall (Fig. **936**). The superior part obliterates the superoposterior part and the inferior part—the inferoposterior part of the cavity (Fig. **936**). Alternative incisions make the inferior and superior flaps longer and more mobile (Fig. **937**), but the blood supply may be damaged and this type of flap may turn into fibrous tissue. The small flaps are cut at their pedicles superiorly and inferiorly, remaining attached distally to the main flap. After the fascia has been adapted and placed anterior to the flap, the large Palva flap is turned into the anterior part of the cavity. The superior and inferior flaps obliterate the superior and inferior part of the cavity, respectively (Fig. **938**).

The great advantage of the broad-based Palva flap is the firm closure of the ear canal. The flap fills the small cavities totally; in large cavities, the tissue is too small to obliterate the entire cavity, and in such cases Palva initially used Gelfoam to fill out the space behind the flap (Fig. **939**). This means that the flap will retract during the early postoperative period. Svane-Knudsen (1967) performed only partial obliteration with a Palva flap, leaving the attic and the aditus open, only covered by fascia

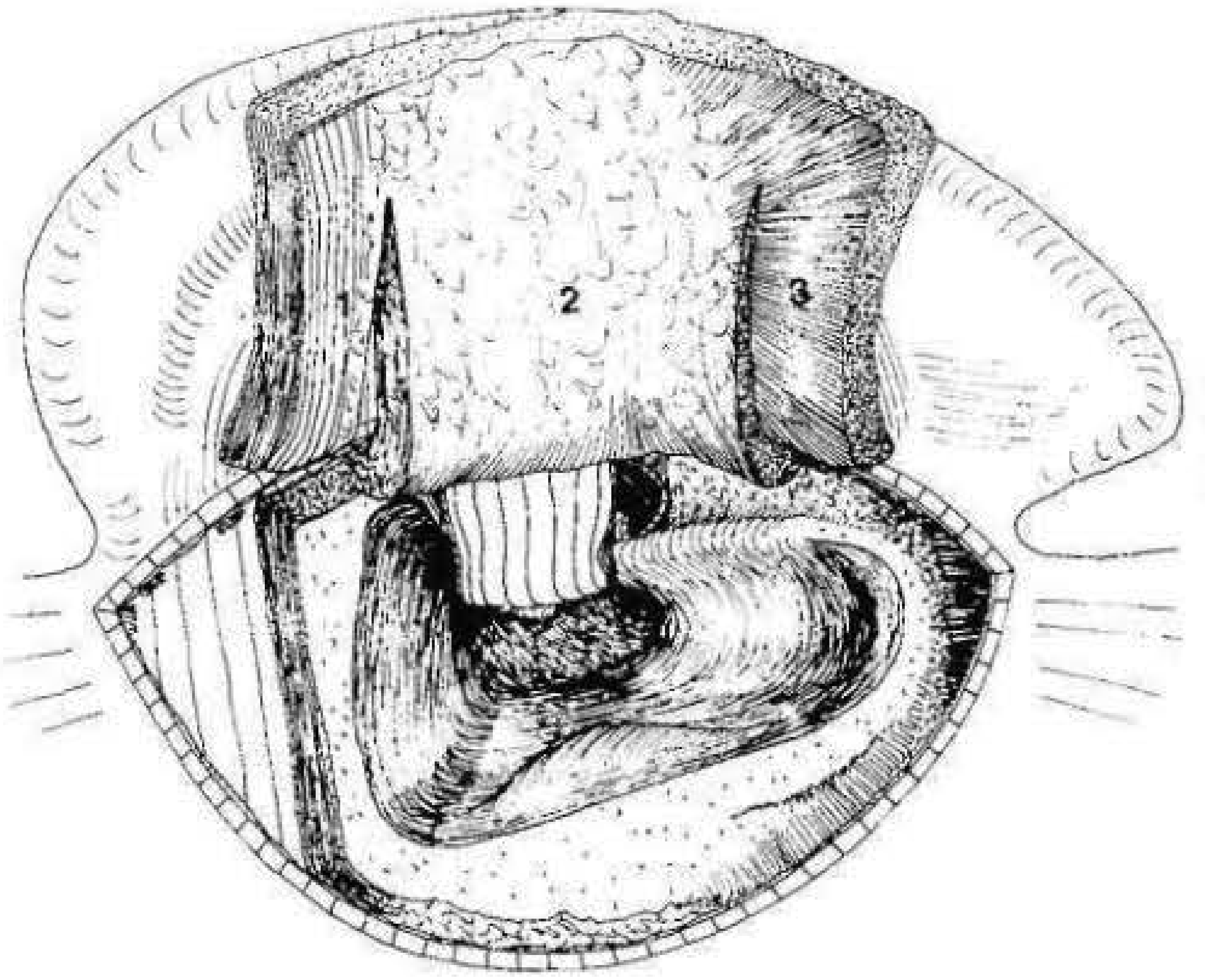


Fig. **937** An alternative way of cutting the enlarged Palva flap. The superior (1) and inferior (3) flaps are incised at the base, and are connected to the main flap (2) at their distal parts. The fascia covers the ear canal flaps **from behind**

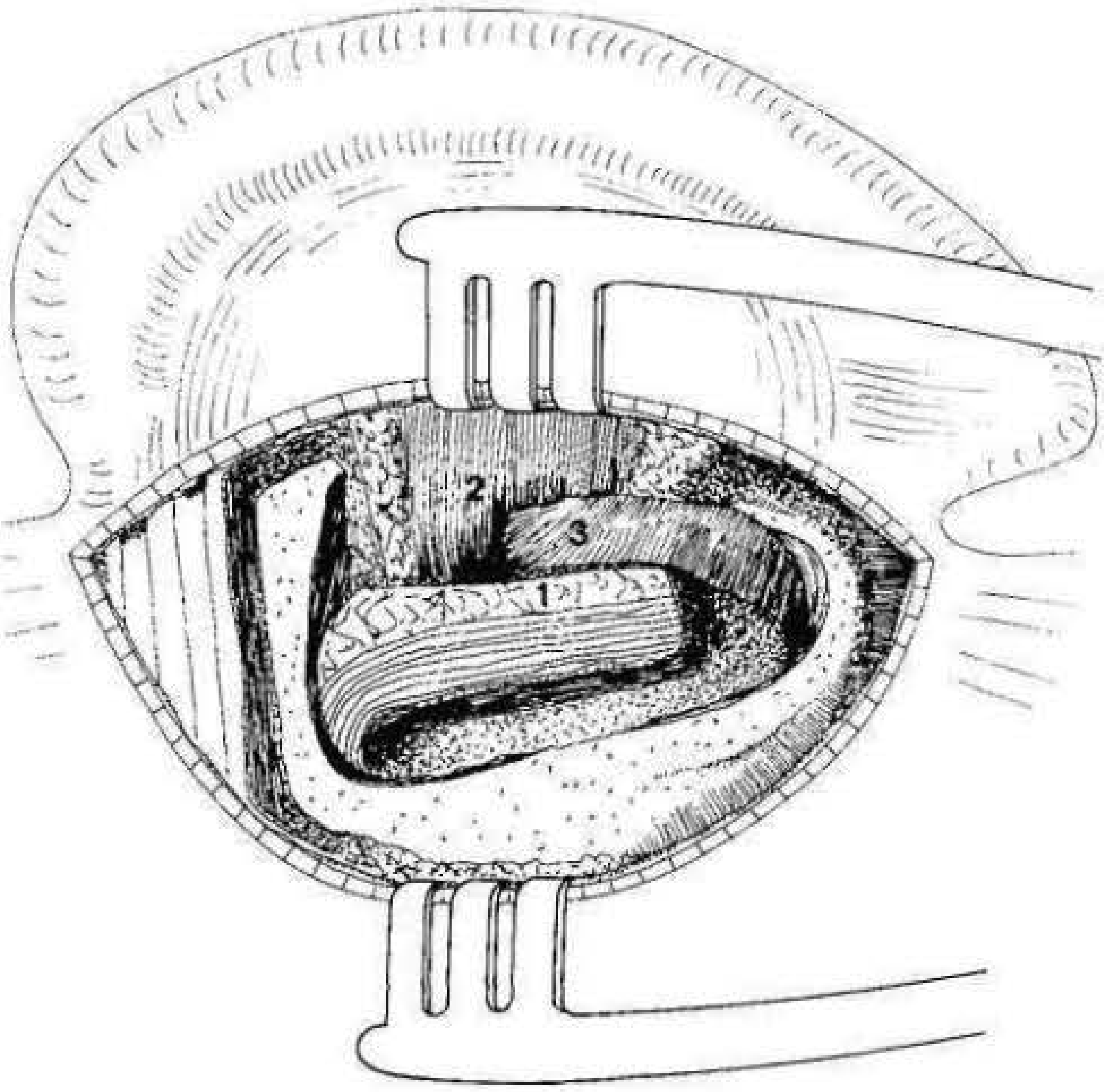


Fig. **938** The large Palva flap (2) obliterates the anterior part of the cavity reconstructing the ear canal. The superior flap (1) obliterates the superior part, and the inferior flap (3) obliterates the inferior part of the cavity

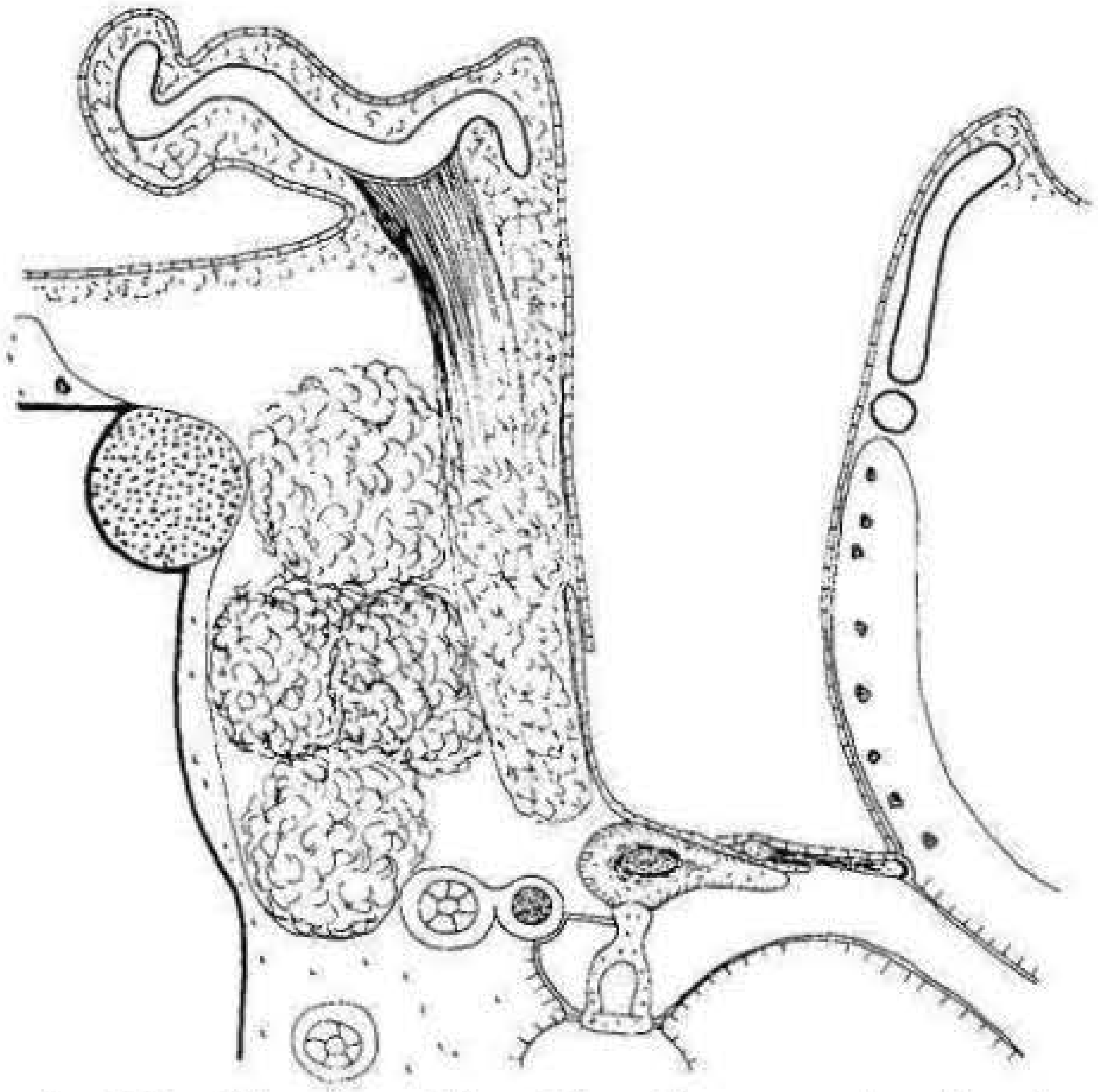


Fig. **939** Side view of the Palva flap reconstructing the ear canal. An incus interposition is performed. The fascia is placed under the malleus handle, and continues laterally along the muscle flap under the meatal skin flap. Posterior to the Palva flap, the space is filled with Gelfoam

(Fig. **940**). He covered the bone with fascia, but he left the edge of the muscle uncovered, risking epithelial ingrowth under the flap (Fig. **940**).

Partial obliteration, in the author's opinion, often results from an inadequate volume of the flap. Sometimes partial obliteration is desirable, but covering of the muscle flap with fascia should always by performed in order to guide epidermization of the ear canal and prevent unwanted ingrowth of the squamous keratinized epithelium under the flaps (Fig. **941**).

After 1973, Palva applied bone paté instead of Gelfoam behind the flap (see Chapter 20). After 1980, Palva consistently tried to keep the canal skin as an intact tube, patching the defect in Shrapnell's membrane with a medially-placed fascial graft and packing the ear canal before turning the musculoperiosteal flap into the cavity to support the posterior skin wall (Palva 1989).

The Palva obliteration method for old radical cavities is performed in two stages by Charachon et al. (1989). In the first stage, the cavity is obliterated with a Palva flap and the ear canal is reconstructed with a large fascial graft, using a large piece of Silastic within the tympanic cavity. In the second stage, performed 12–18 months after the first, the ossiculo-

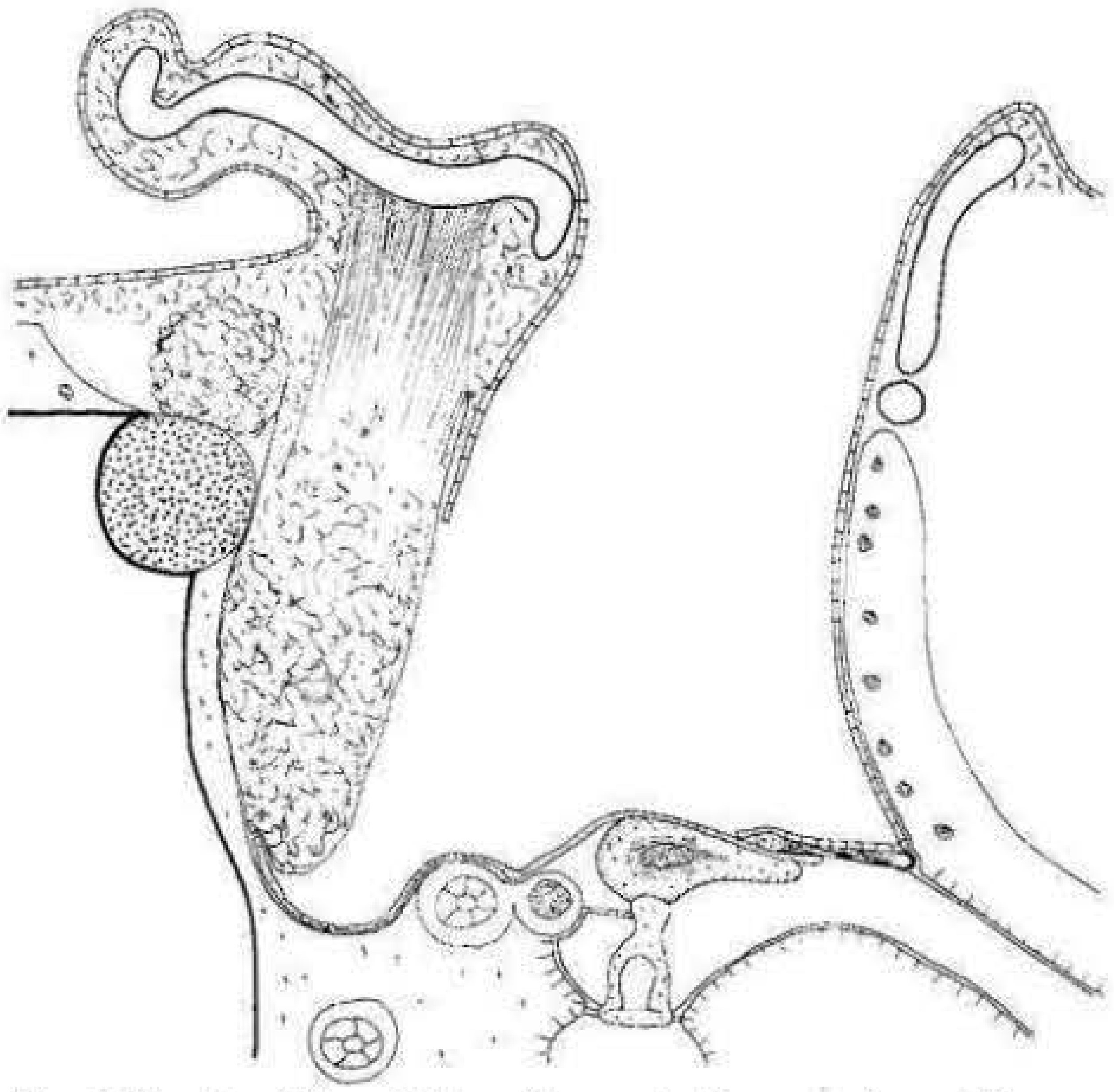


Fig. **940** **Partial obliteration of the cavity with a Palva flap, as modified by Svane-Knudsen.** The ear canal is widened, and the attic and aditus ad antrum are an open cavity. After ossiculoplasty with the incus, the fascia is placed under the malleus handle, It covers the facial prominence, the prominence of the lateral semicircular canal, and the denuded bone of the aditus ad antrum. It ends *under* the muscle flap. The Palva flap is pushed posteriorly, and the ear canal is widened

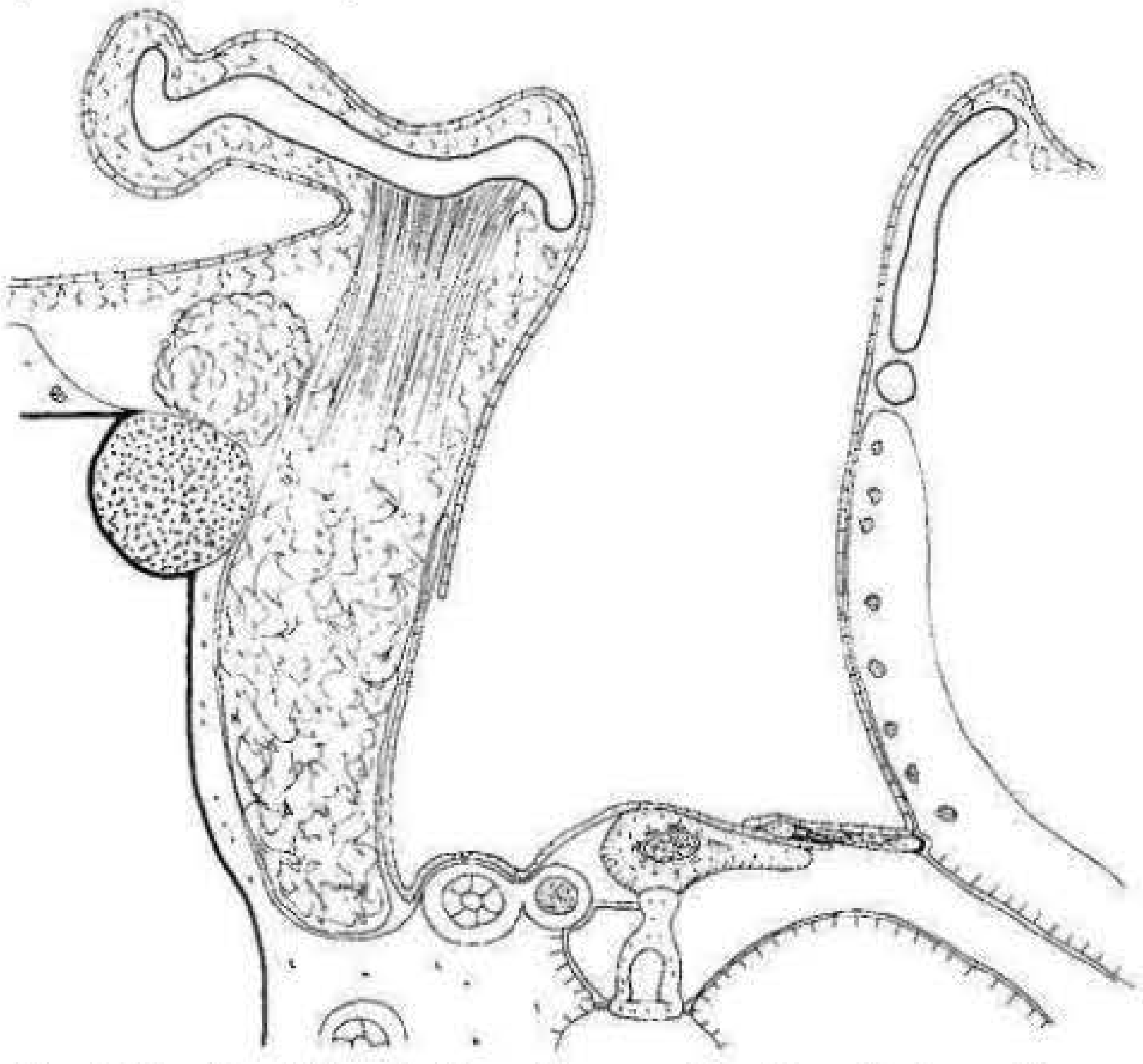


Fig. **941** **Partial obliteration with the Palva flap covered with fascia.** After incus interposition, the fascia covers the perforation as an underlay graft. It continues over the prominence of the lateral semicircular canal to the Palva flap, covering it as far as the canal skin flap. Epithelialization will be guided by this method, and the keratinized epithelium cannot grow underneath the Palva flap. The ear canal is widened, and the aditus ad antrum and attic remain open plasty is performed, and the Silastic is removed. No cholesteatoma has been observed behind the flaps. Palva himself performs this surgery in one stage, using a broader and larger musculoperiosteal flap than usual (Palva 1962b).

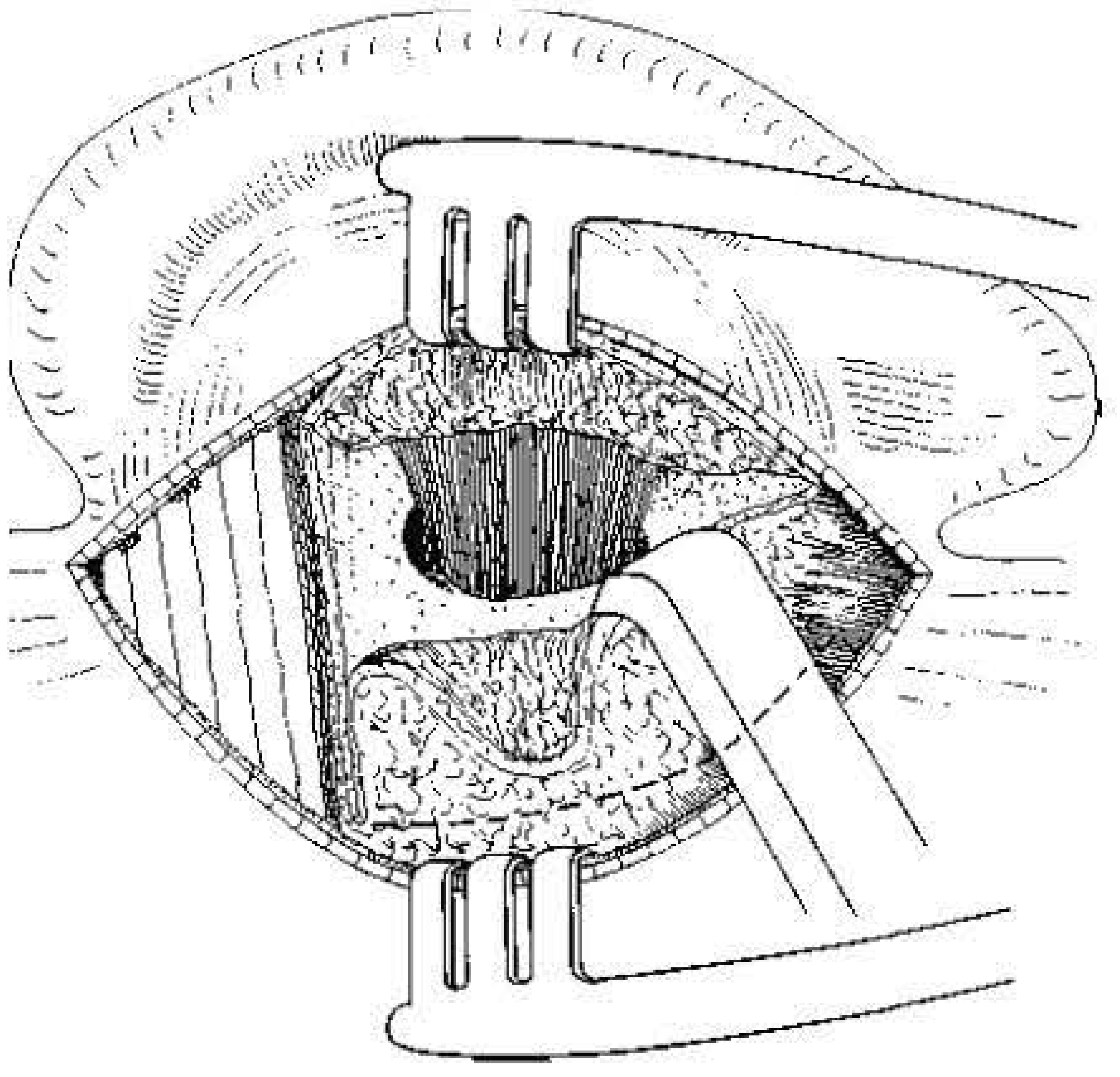


Fig. **942** **The Meurmann inferiorly-pedicled flap in a retroauricular approach.** A retroauricular incision through the skin, and a T-incision through the subcutis and periosteum, are made. The horizontal incision runs along the inferior edge of the temporalis muscle, and the vertical one runs along the ear canal toward the mastoid tip. The anterior flap is elevated, exposing the ear canal skin. The posterior flap is elevated posteriorly. The dashed line indicates the posterior incision line through the subcutis, muscle, and periosteum

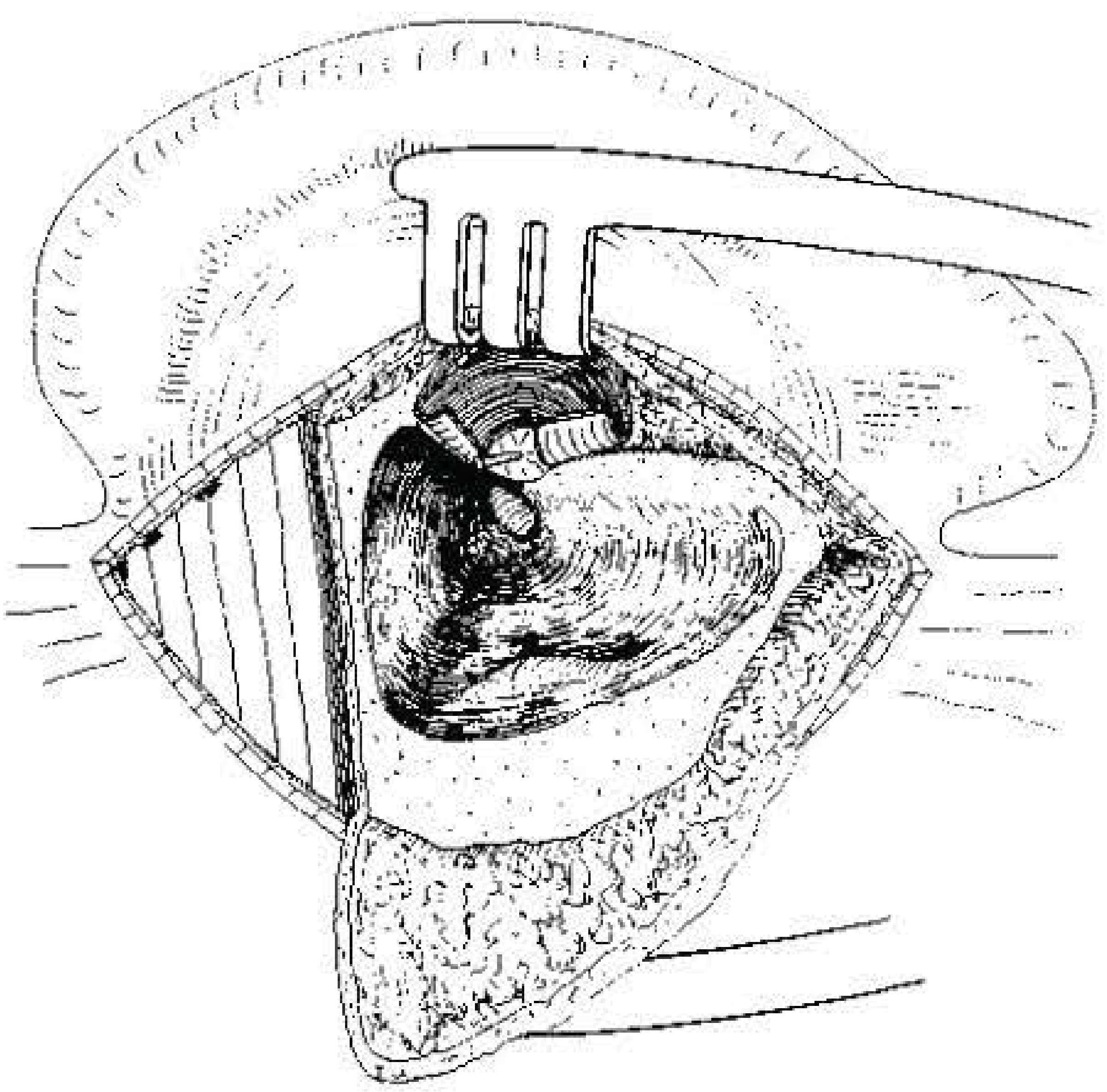


Fig. **943** A large Körner flap and a Stacke flap are elaborated, and a canal wall–down mastoidectomy is carried out. The musculoperiosteal flap is held in place by a self-retaining retractor during the mastoidectomy

Inferiorly Based Flaps

The inferiorly-based flaps are developed from the subcutis–muscle–periosteal tissue behind the posterior margin of the postauricular incision, but they can also involve part of the temporalis muscle or part of the sternocleidomastoid muscle. Their advantage is ease of obliteration of the mastoid tip and the inferior part of the cavity. Their disadvantage is the difficulty in obliterating the sinodural angle and the superior part of the cavity. They cannot be used to reconstruct the ear canal to the same extent as the anteriorly-based Palva flap.

Meurmann's Musculoperiosteal Flap

Meurmann's pedicled musculoperiosteal flap, used since 1938 at Helsinki Clinic, was the first mesenchymal flap used for obliteration of radical cavities (Meurmann and Ojala 1949).

Meurmann's flap with the retroauricular approach. In the retroauricular approach, the skin is incised and elevated posteriorly (Fig. **942**). The incisions are performed through the subcutis and periosteum. The horizontal incision goes along the inferior edge of the temporalis muscle, and the vertical incision runs along the line of the ear canal toward the mastoid tip. The anterior flap is elevated, exposing the ear canal skin. The large posterior musculoperiosteal flap is completely elevated, exposing the mastoid process. The flap is held in place during the mastoidectomy by a selfretaining retractor. A large Körner flap and a Stacke canal skin flap are elaborated. The canal wall–down mastoidectomy is performed (Fig. **943**). The muscoloperiosteal flap is cut as far posteriorly as possible, including the splenius capitis and transversus nuchae muscles, as well as the sternocleidomastoid muscle (Fig. **944**). The flap is partly double-folded, placed in the inferior part of the cavity, and secured with a couple of catgut sutures to the anterior subcutis–periosteal flap and inferior conchal cartilage (Fig. **945**). The Körner flap is pulled posteriorly and fixed. The Stacke flap is replaced on the facial ridge, and the medial and superior walls of the cavity are primarily covered with split-skin grafts.

Meurmann's flap has also been used *in the endaural approach(Fig.* **946**). After elevation of the

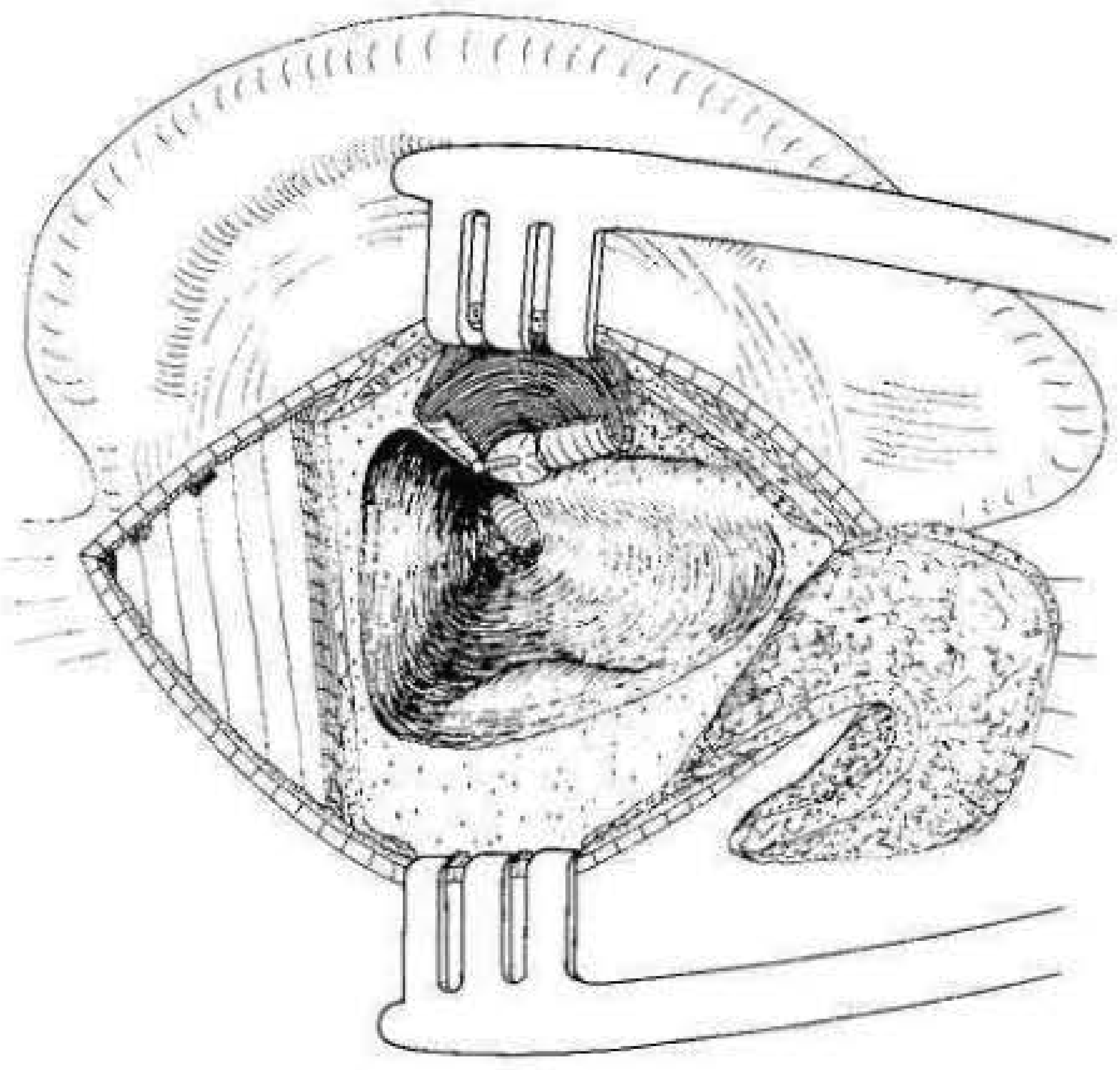


Fig. **944** The inferiorly-pedicled subcutis–musculoperiosteal flap is cut and elevated, involving the splenius capitis and transversus nuchae muscles, as well as the sternocleidomastoid muscle

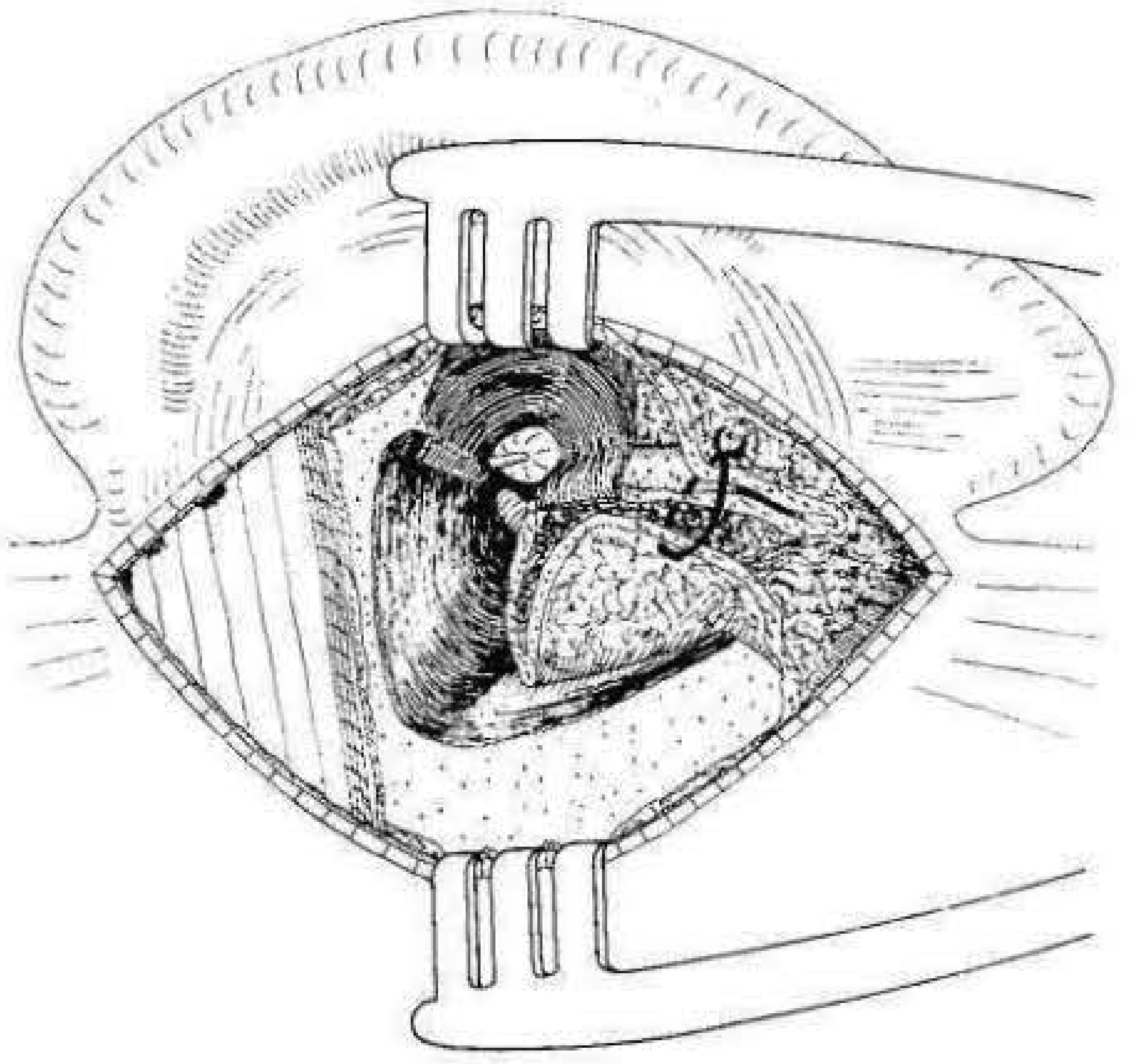


Fig. **945** The partly double-folded flap is placed in the inferior part of the cavity and sutured with a couple of catgut sutures to the antrior subcutis–periosteal flap and the fibrous tissue covering the inferior conchal cartilage

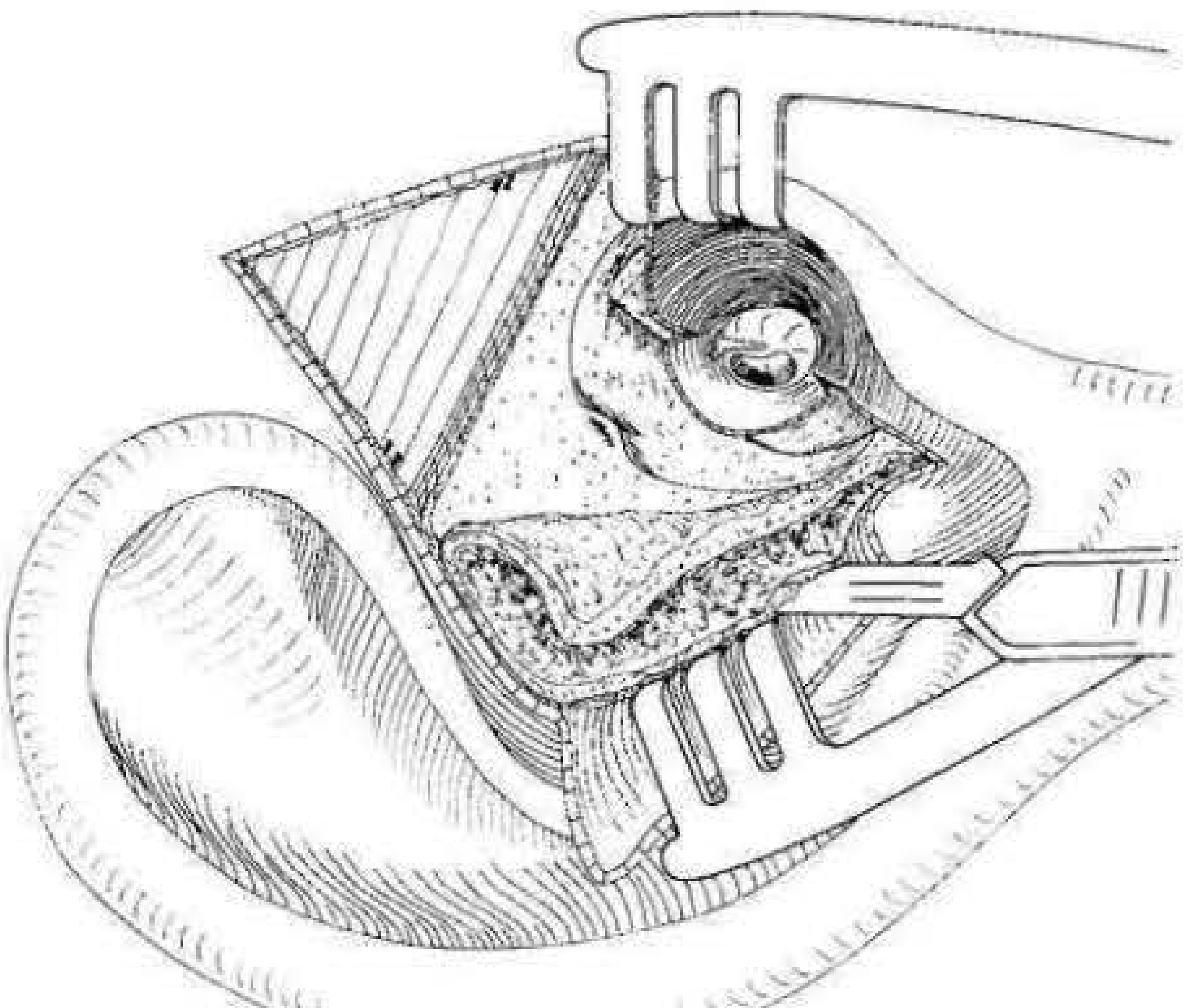


Fig. **946** **The Meurmann inferior pedicled flap in endaural approach.** An endaural approach is made, exposing the mastoid area by elevating a large, laterally-based ear canal skin flap. The subcutis and periosteum are incised along the inferior border of the temporalis muscle. The flap is elevated, and further incised posterior to the mastoid tip

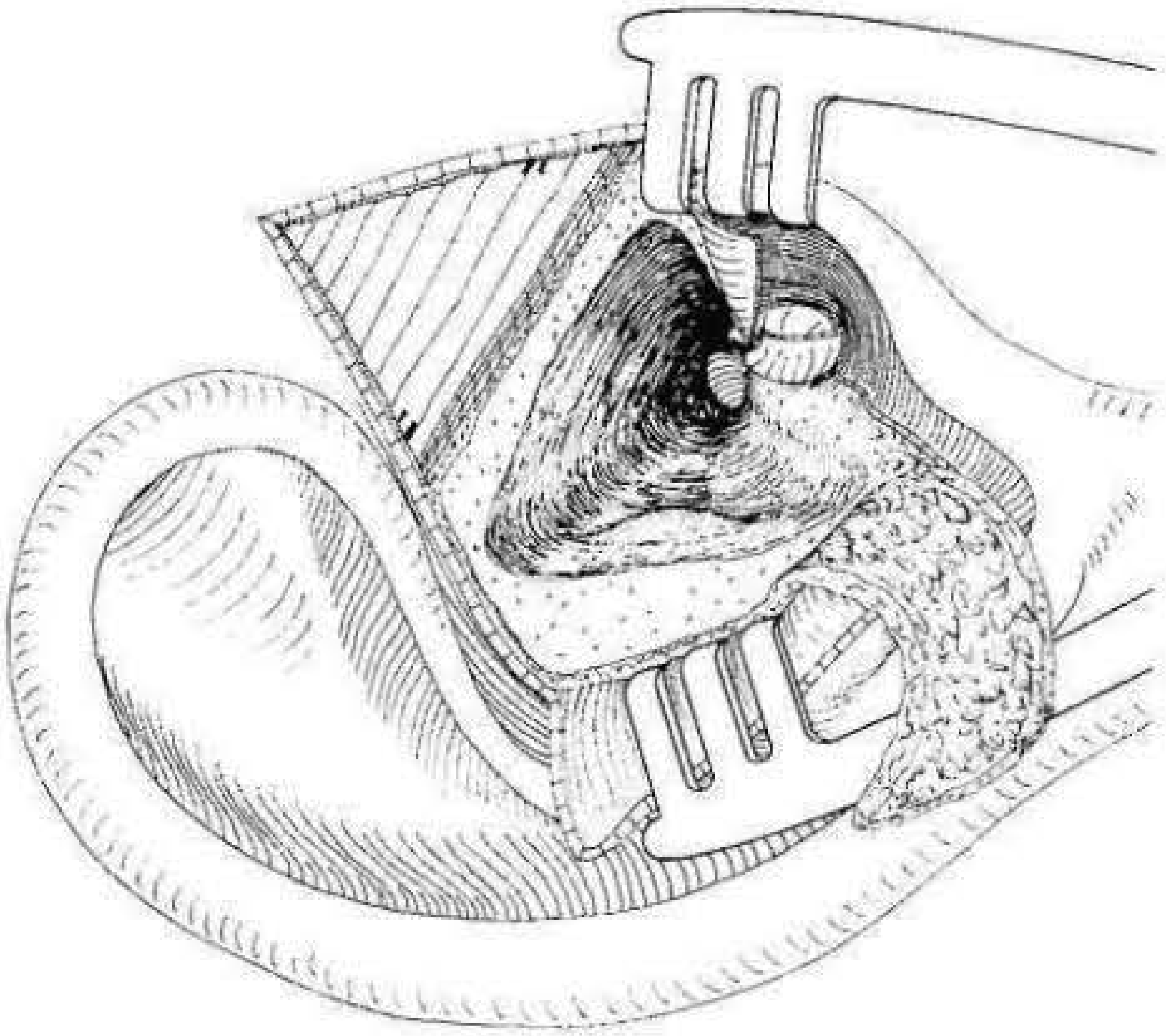


Fig. **947** A canal wall–down mastoidectomy is carried out, with removal of the bridge, resection of the malleus head, and extrusion of the incus. The inferiorly-pedicled subcutis–muscle–periosteum flap is completely elevated

skin posteriorly, the subcutis and periosteum are incised along the border of the temporalis muscle as far posteriorly as possible. A musculoperiosteal flap based inferiorly is elevated, and a canal wall-down mastoidectomy is performed (Fig. **947**). The subcutis–muscle flap is placed, partly double-folded, in the inferior half of the cavity. It is secured to the ear canal flap with a catgut suture (Fig. **948**).

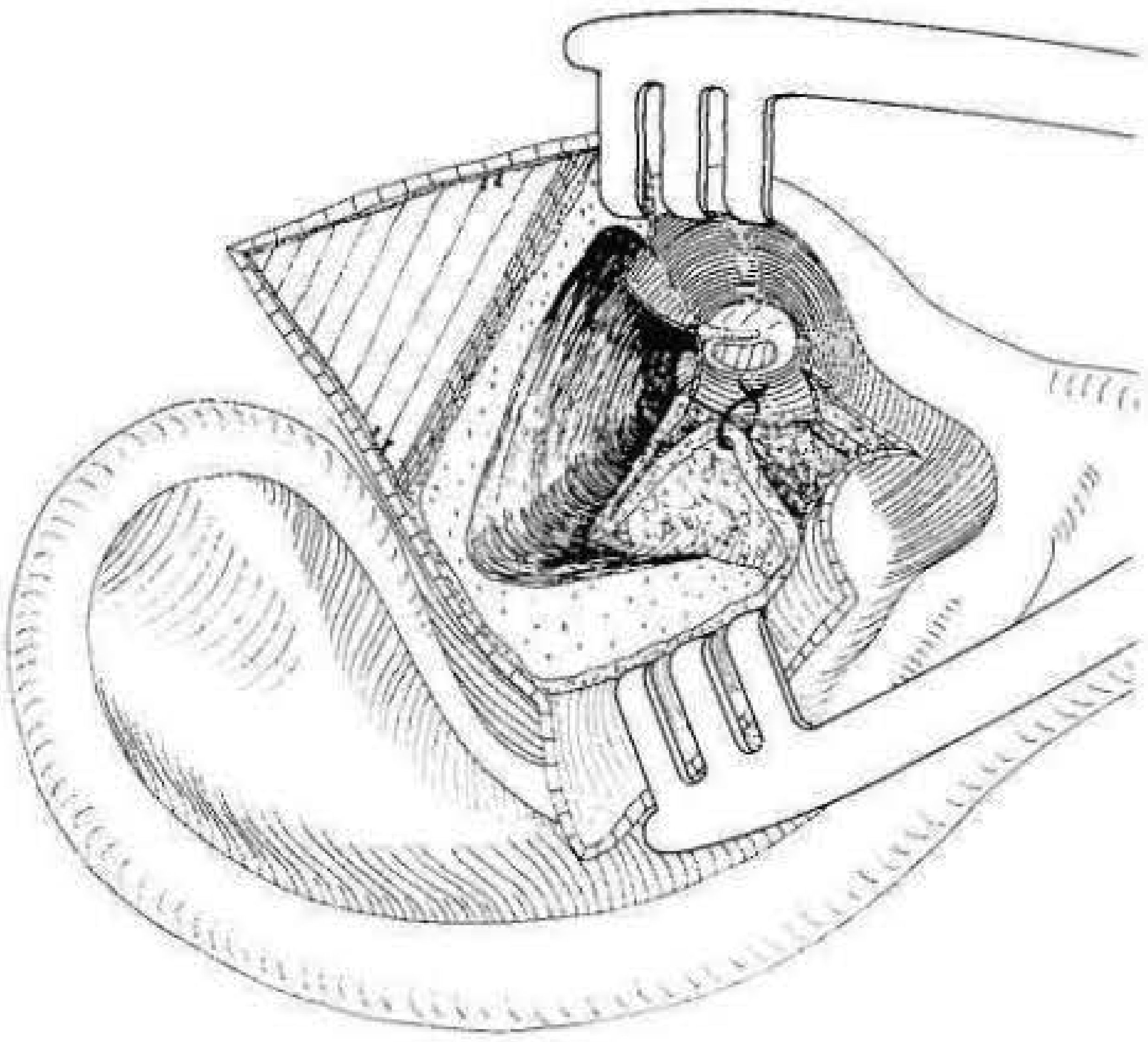


Fig. **948** The subcutis–muscle flap is placed, partly double-folded, in the inferior half of the cavity, and fixed to the ear canal flap with a suture

The Guilford Inferiorly-Based Flap

The Guilford inferiorly-based flap (Guilford 1960) is harvested through a separate, inferiorly-positioned retroauricular incision *after* the canal wall–down mastoidectomy has been performed through the endaural approach. If the mastoid air cells extend into the mastoid tip, Guilford then exenterates them using the retroauricular incision.

After endaural exenteration of accessible air cells, an inferior retroauricular incision is made (Fig. **949**). The skin is elevated, and the subcutis-musculoperiosteal flap is incised as far posteriorly as possible (Fig. **950**). After elaboration of the inferiorly-pedicled flap, the remaining air cells from the mastoid tip are exenterated (Figs. **951, 952**). The flap is placed in the inferior part of the cavity (Fig. **953**).

The difference between the Guilford and the Meurmann flap is that Guilford uses two approaches. Both flaps are short and cannot really obliterate the superior part of the cavity. In case of extensive pneumatization, Guilford (1960) recommends removal of the mastoid tip in continuity with the inferior flap. This technique is described in Chapter 11.

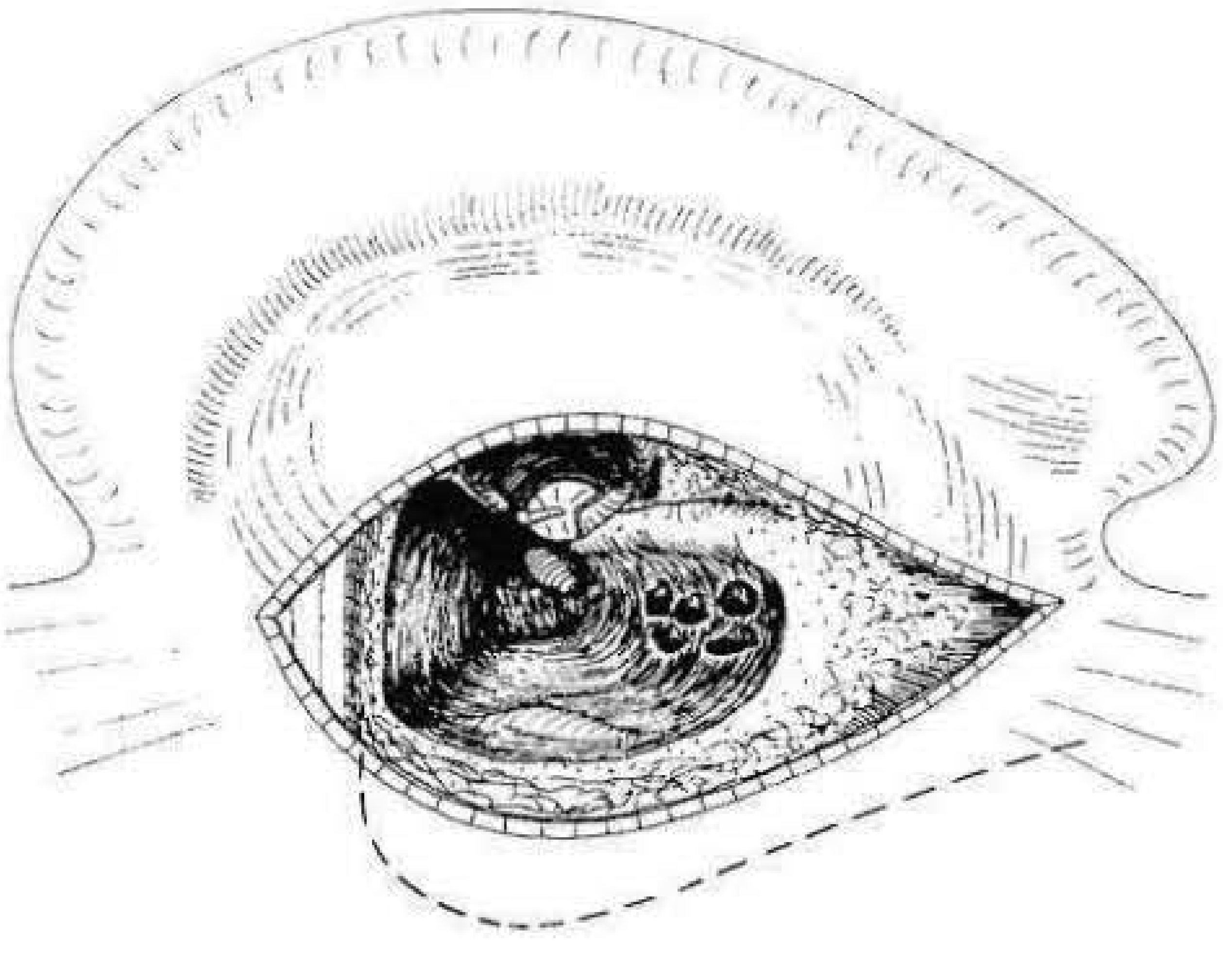


Fig. **949** **The Guilford inferiorly-pedicled flap.** In the endaural approach, a canal wall–down mastoidectomy with removal of the bridge if carried out. Via a postauricular incision, placed somewhat inferiorly, the inferiorly-pedicled flap will be harvested. The dashed line indicates the size of the flap

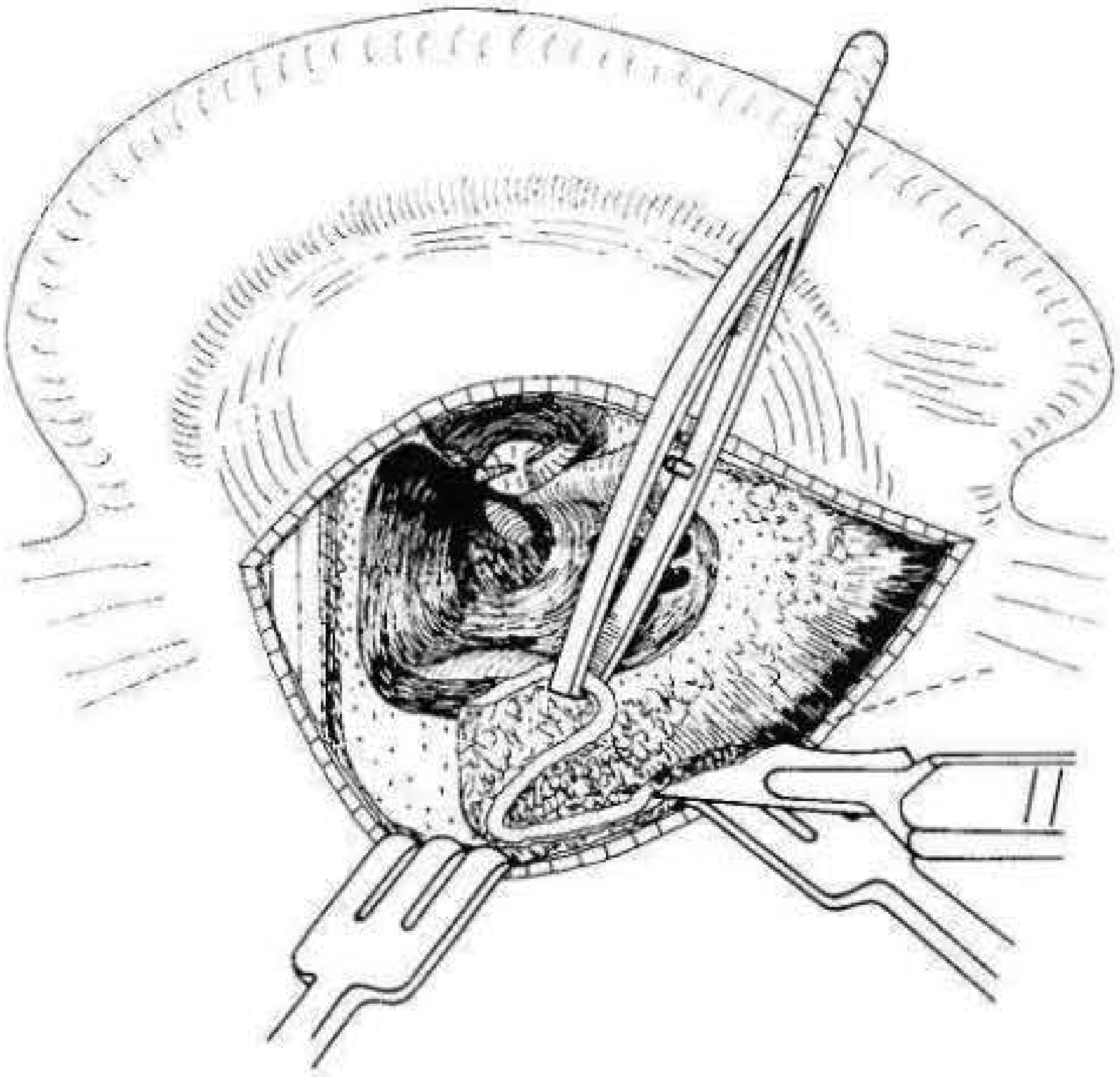


Fig. **950** The subcutis–musculoperiosteal flap is incised as far posteriorly as possible and elevated

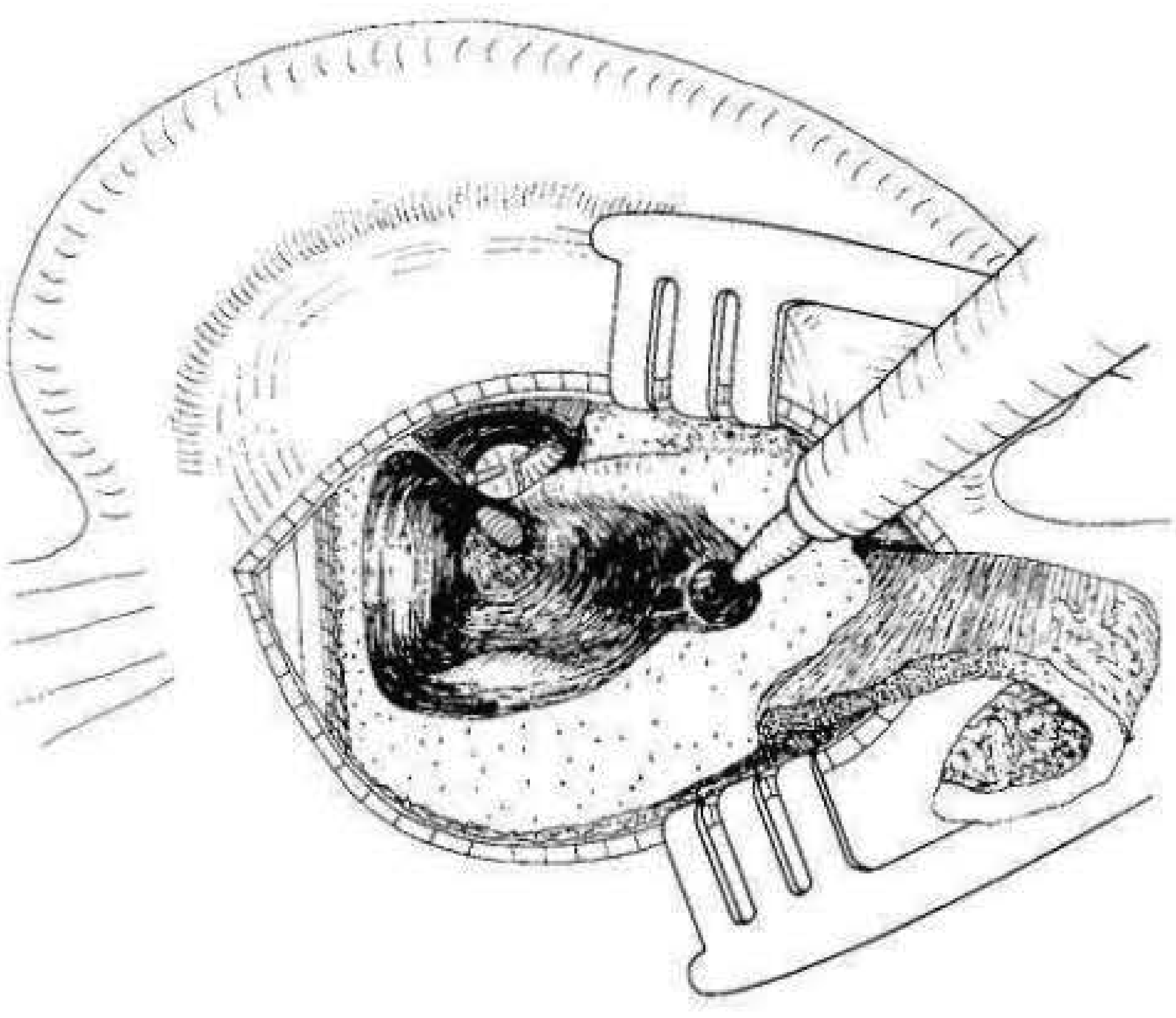


Fig. **951** The remaining cells of the mastoid tip are exenterated with a cutting burr, and the cavity is enlarged inferiorly. The subcutis–muscle–periosteum flap is completely elevated

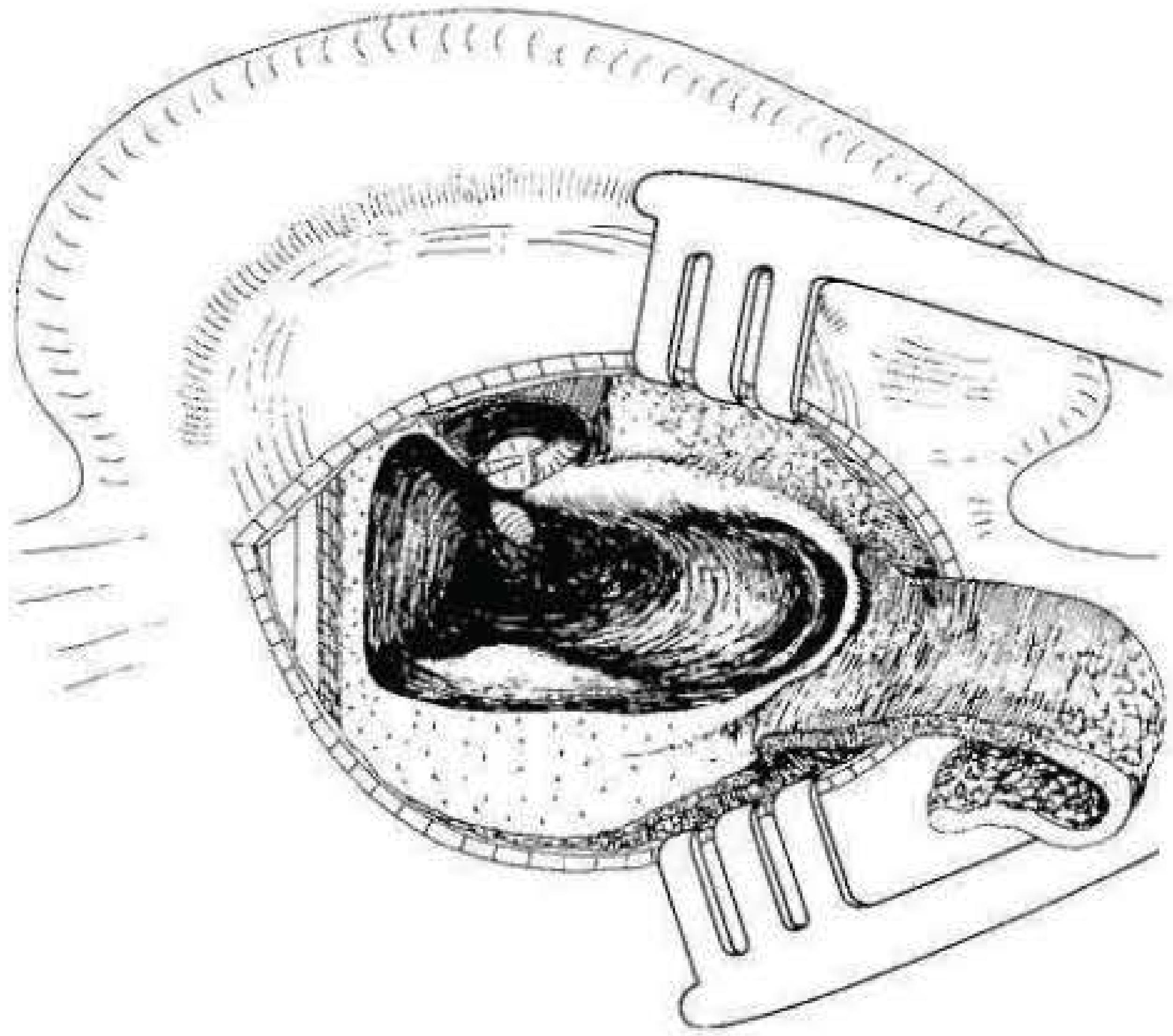


Fig. **952** All cells from the mastoid tip are exenterated, resulting in a large cavity

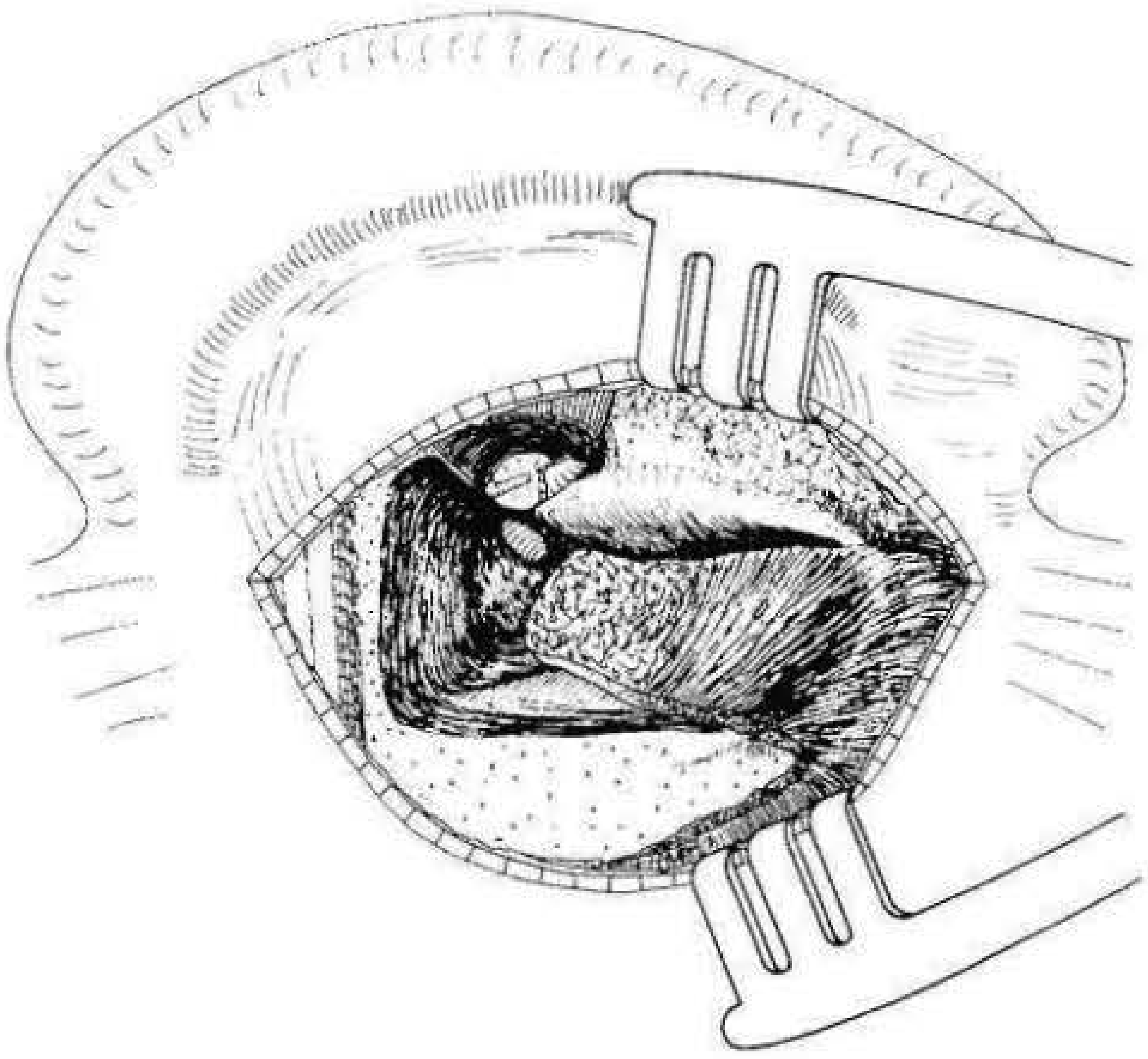
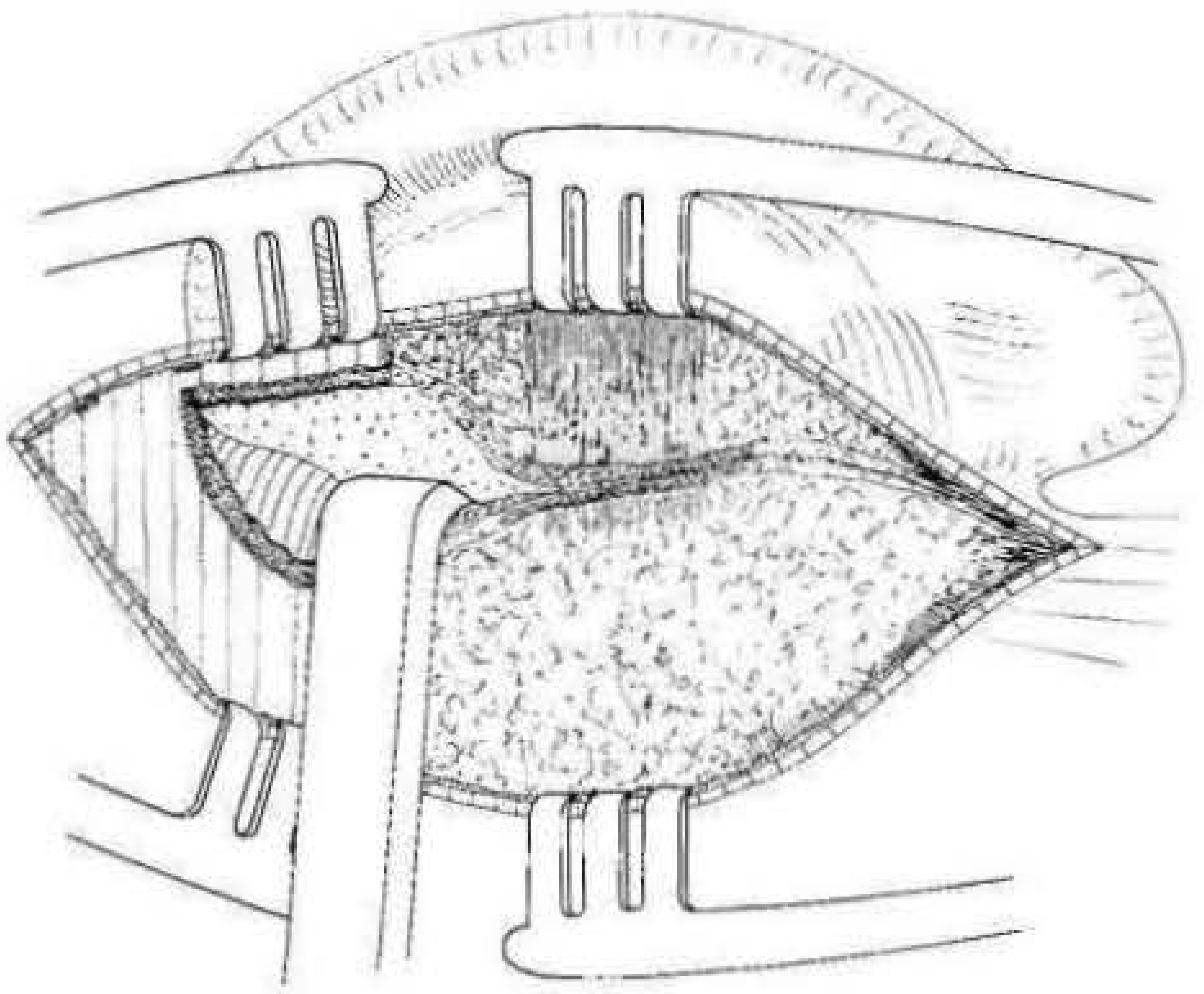


Fig. **953** The inferiorly–pedicled subcutis–muscle–periosteum flap obliterates the inferior half of the cavity

The Hilger and Hohmann Flap

Hilger and Hohmann (1962) introduced a large inferiorly-pedicled flap involving part of the temporalis muscle and all the retroauricular fibrous tissue, as well as the periosteum with the postauricular muscle, splenius capitis muscle, and transversus nuchae muscles,

After a large retroauricular incision, the skin is elevated, especially posterior to the incision. A subcutis–periosteum incision is then made along the posterior edge of the ear canal. The incision is continued inferiorly to the mastoid tip. Superiorly, the incision is continued through the temporalis muscle for about 2 cm. The temporalis muscle and the fibrous tissue are elevated and retracted posteriorly (Fig. **954**), exposing the entire cortex of the mastoid process. A lateral circumferential incision of the ear canal skin is performed from the 12-o'clock to the 6-o'clock positions (Fig. **955**). The lateral part of the ear canal skin is retracted, and the medial part is elevated from the bone. A canal wall–down mastoidectomy is performed (Fig. **956**). The large mesenchymal flap is elevated and incised along the posterior edge of the wound to the mastoid tip (Fig. **957**). The flap is placed in the cavity. It covers all the walls, and even obliterates the sinodural angle (Fig. **958**). The epithelial flaps from the ear canal are replaced, and the ear canal is widened by incisions at the 12-o'clock and 6-o'clock positions.



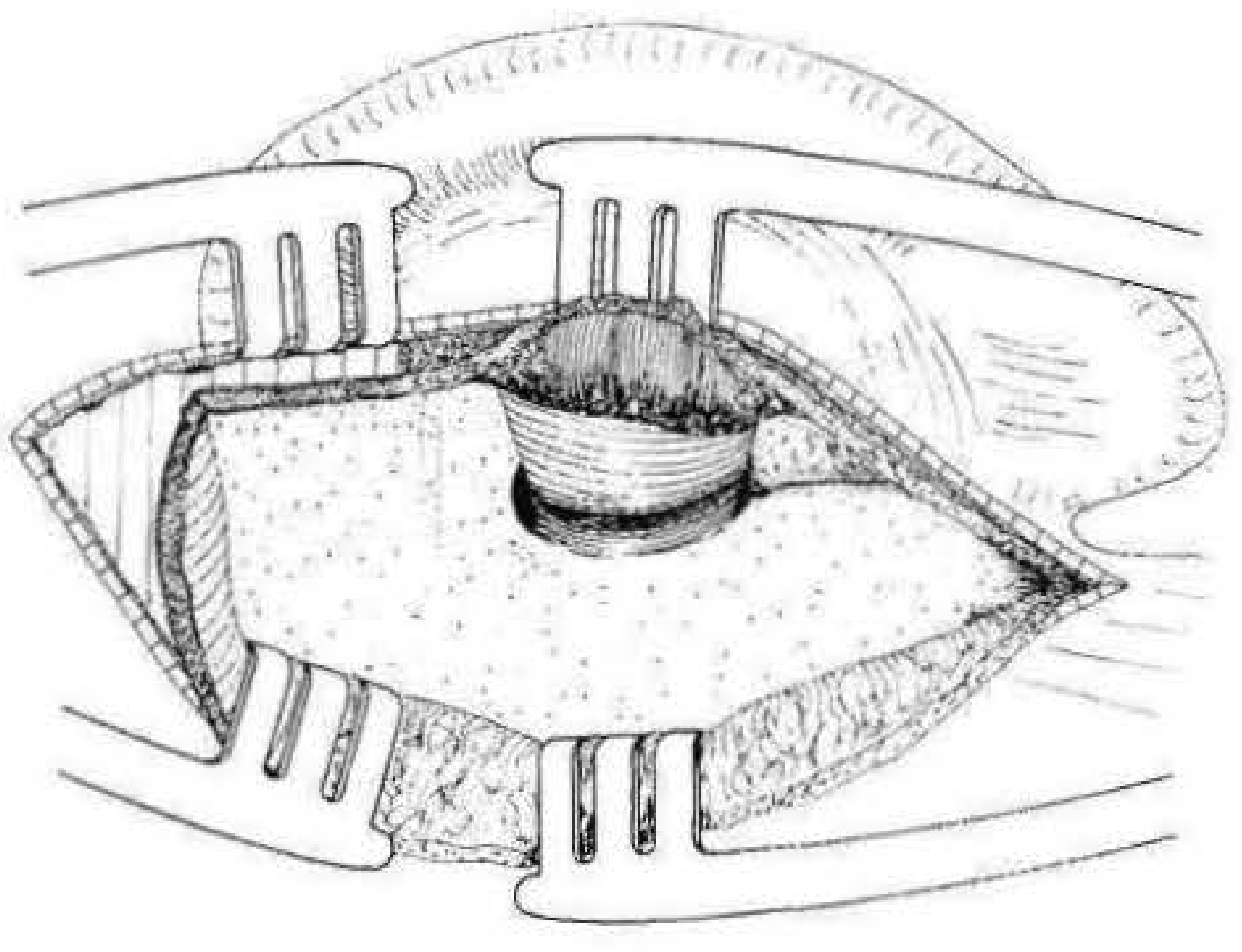


Fig. **954** **The Hilger and Hohmann inferiorly-pedicled flap.** A large retroauricular skin incision and a long anterior incision are made through the inferior part of the temporalis muscle, and the subcutis, muscle, and periosteum, extending to the mastoid tip. The subcutis–muscle–periosteum flap is elevated posteriorly

Fig. **955** The flap is maximally elevated, held in place by two selfretaining retractors, and the mastoid process is exposed. In the ear canal, a lateral circumferential skin incision is made between the 12-o'clock and 6-o'clock positions

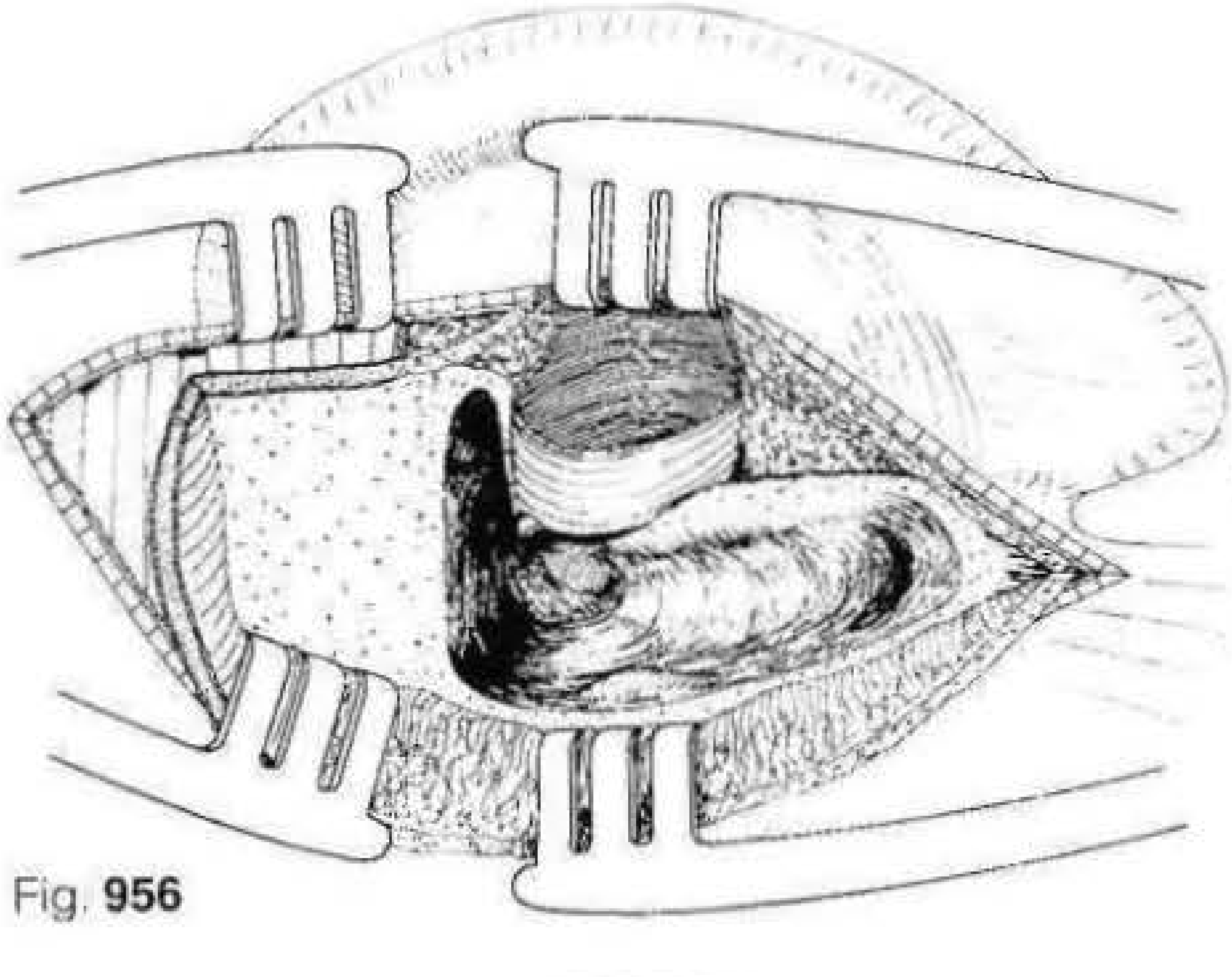


Fig. **956**

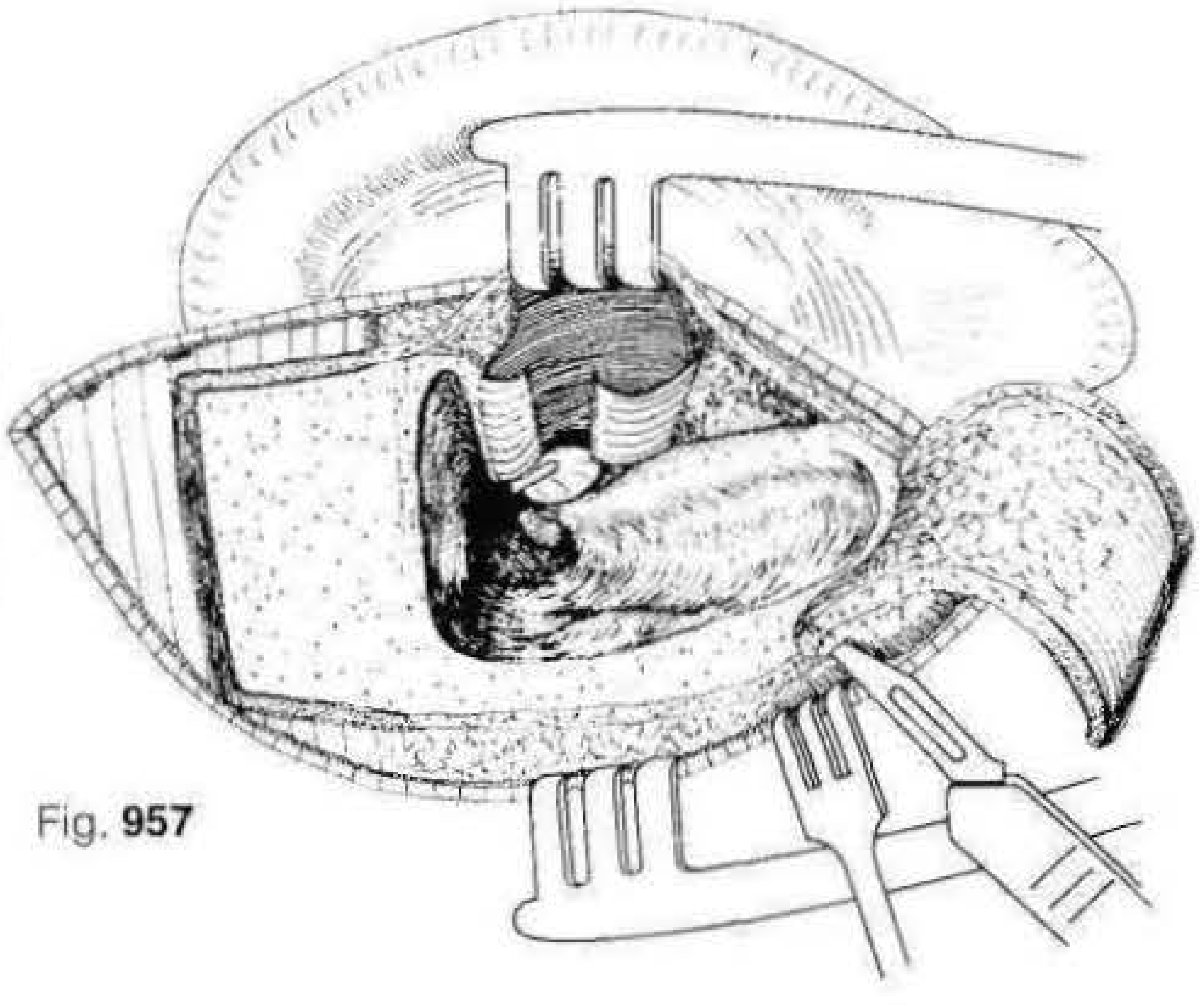


Fig. **957**

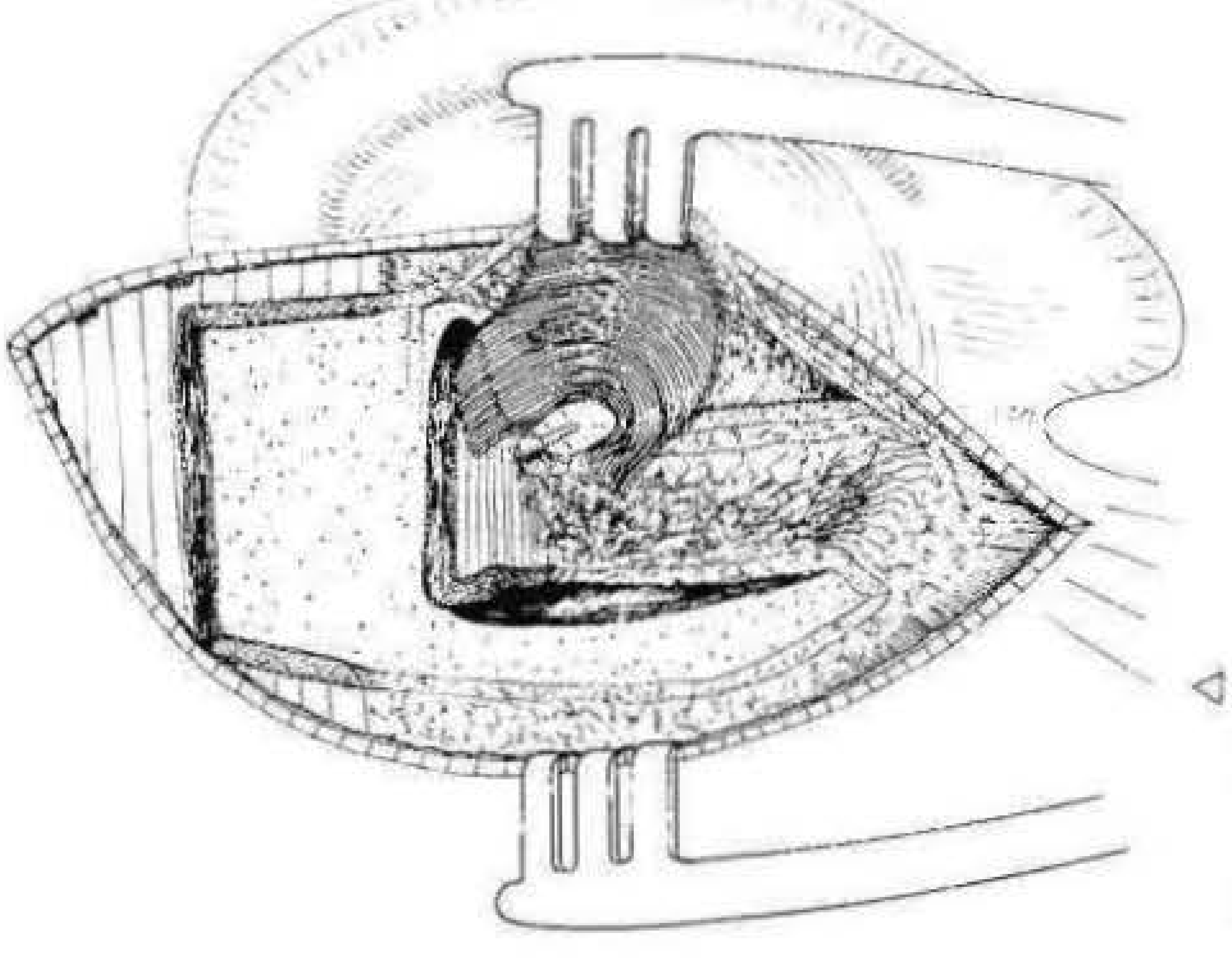


Fig. **956** A canal wall–down mastoidectomy is carried out, with removal of the bridge, resection of the malleus head, and extraction of the incus. The lateral part of the ear canal is elevated

Fig. **957** The inferiorly-pedicled subcutis–musculoperiosteal flap is cut and totally elevated. The ear canal skin is cut at the 9-o'clock position, forming two large flaps

◁ Fig. **958** The inferiorly-pedicled subcutis–musculoperiosteal flap is placed in the cavity. It covers the mastoid tegmen, sinodural angle, and all the remaining walls. The epithelial flaps are replaced, partly covering the muscle flap

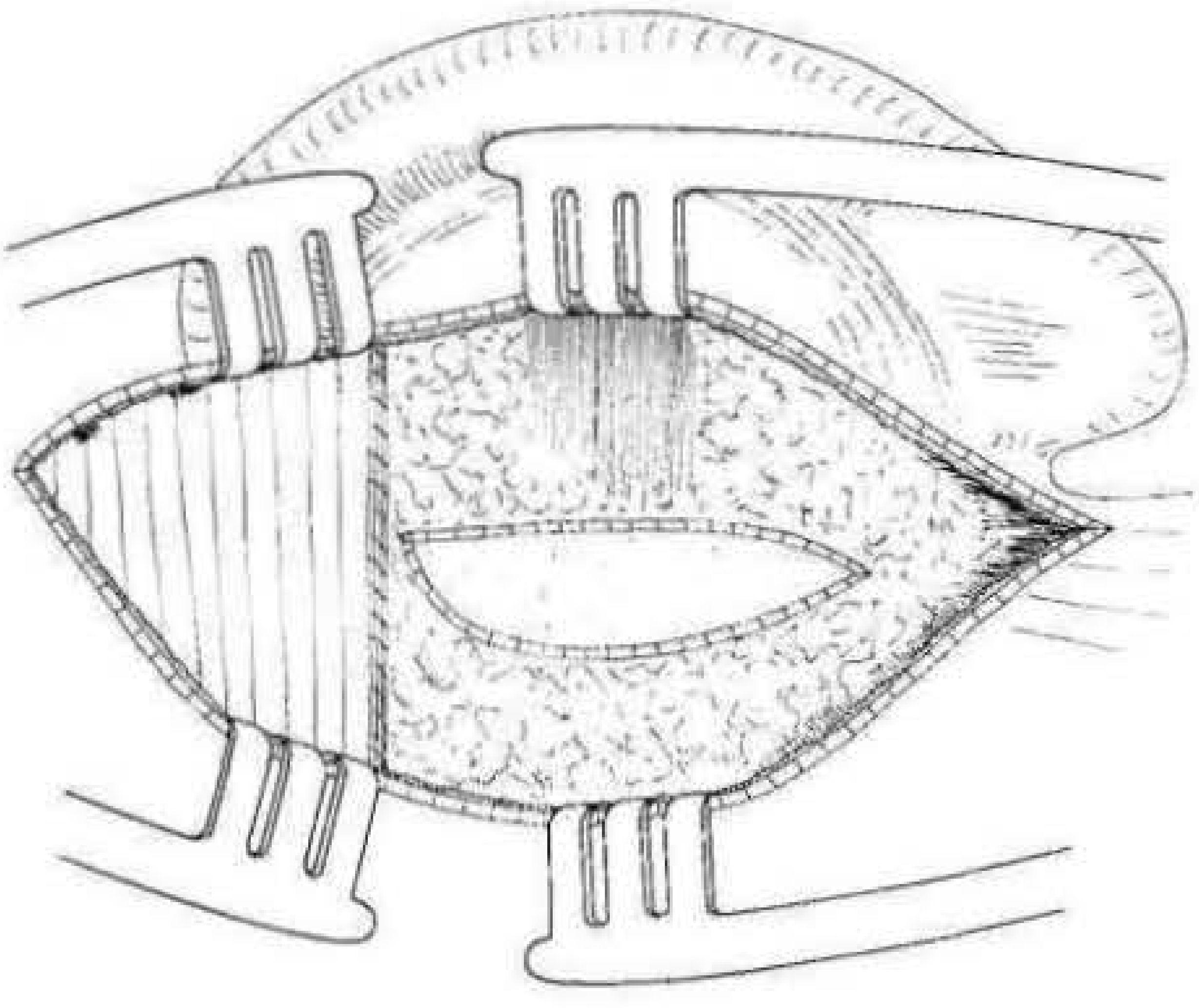


Fig. **959** The Hilger and Hohmann flap, with an island of retroauricular skin, will be placed in the cavity together with the flap at the end of the surgery

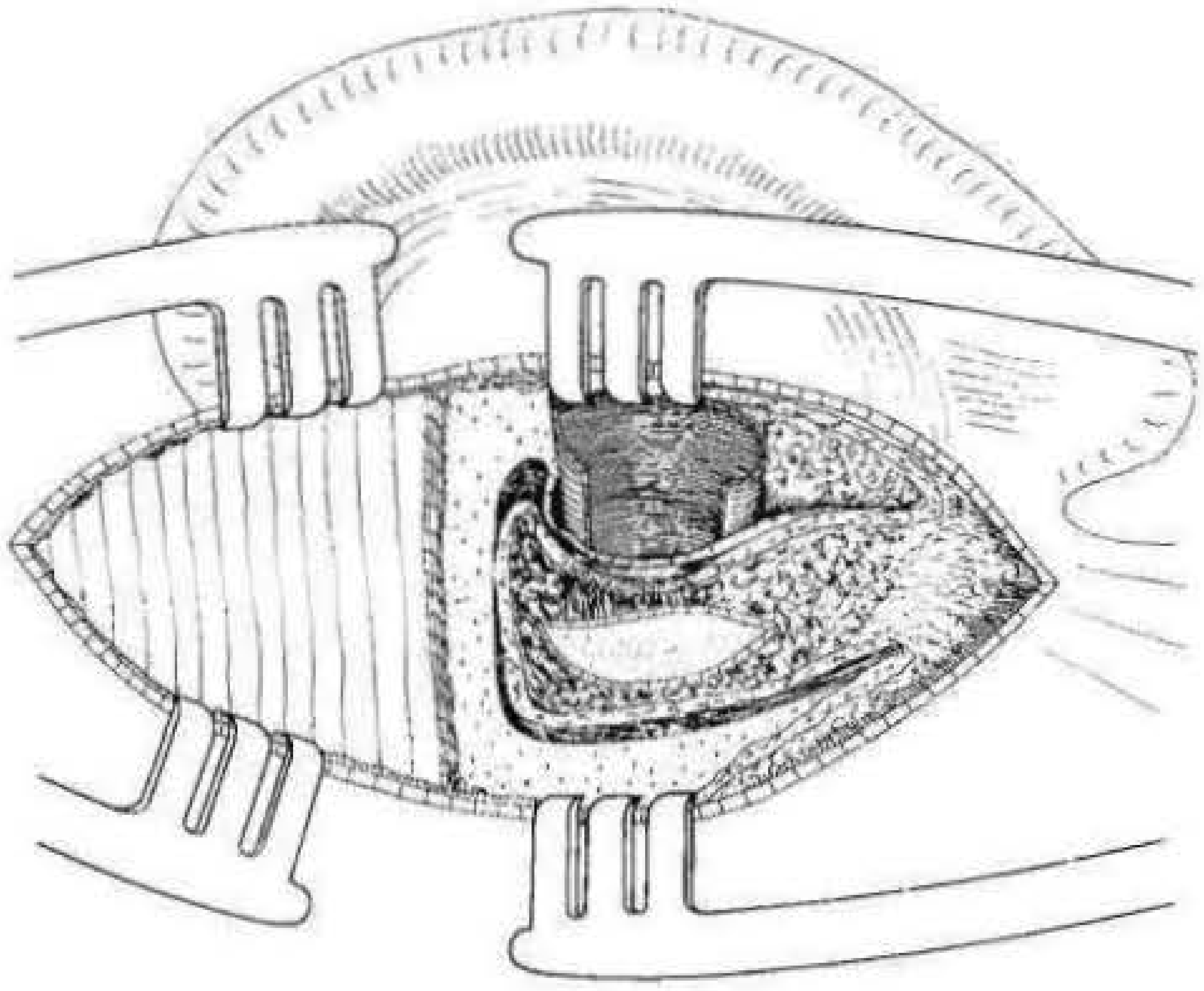


Fig. **960** The subcutis–musculoperiosteal flap, with the island of skin in position

In some cases, an island of postauricular skin is left attached to the mesenchymal flap and brought into the cavity (Fig. **959**) in order to facilitate the epithelialization of the cavity (Fig. **960**).

The Naumann Large Inferiorly Pedicled Flap

Naumann (1966) used a flap similar to that of Hilger and Hohmann (1962) to obliterate the cavity after intact canal wall mastoidectomy. He used temporalis muscle with fascia, subcutaneous tissue, and postauricular muscle, as well as the muscles attached to the mastoid tip (Fig. **961**). Naumann starts with an endaural approach, and a Heermann B incision (see Vol. 1, pp. 15–21), performing all the necessary work within the tympanic cavity. After a large retroauricular incision, the skin is elevated maximally, exposing the entire mastoid process and the inferior part of the temporalis muscle (Fig. **961**). An anterior incision through the temporalis muscle, the fibrous tissue, and the periosteum as far as the mastoid tip, and a parallel posterior incision are made. The incisions are connected superiorly through the temporalis muscle, and the entire flap is elevated (Fig. **962**) as far as the mastoid tip (Fig. **963**). It is protected during the mastoidectomy. An intact canal wall mastoidectomy is then performed (Fig. **964**), and all pathology with in the mastoid process is removed. The large flap is placed in the cavity ofter the attic and aditus ad antrum have first been firmly obliterated, followed by the rest of the cavity (Fig. **965**). Care is taken to obliterate the attic and aditus completely in order to prevent subsequent retraction into the attic.

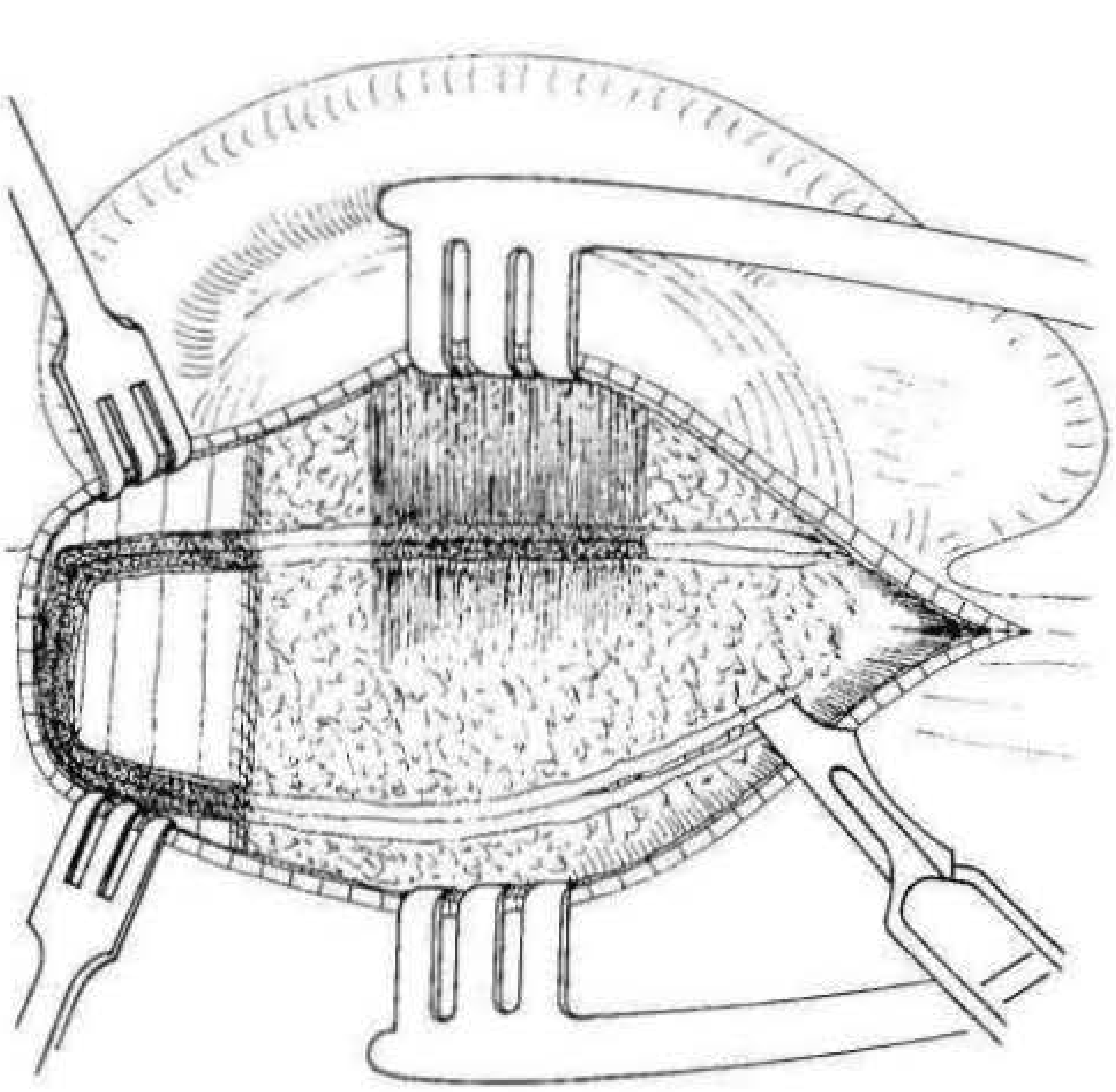


Fig. **961** **The Naumann large inferiorly-pedicled flap.** After a large retroauricular incision, an anterior incision is made through the subcutis, temporalis muscle, and periosteum to the mastoid tip, and a parallel posterior incision is made followed by a horizontal incision through the temporalis muscle, demarcating a long flap

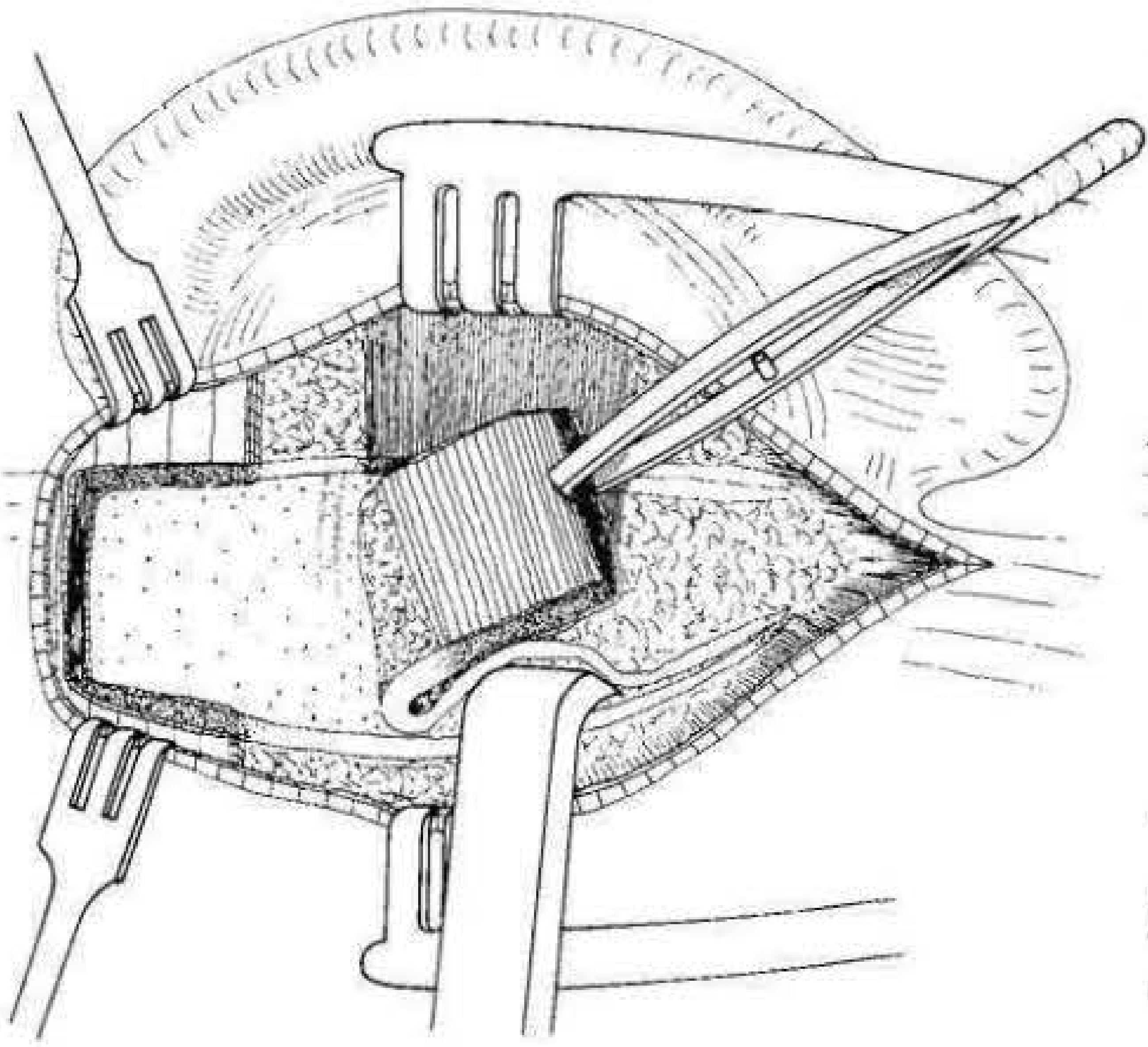


Fig. **962** The flap, consisting of temporalis muscle and subcutis–periosteum, is elevated

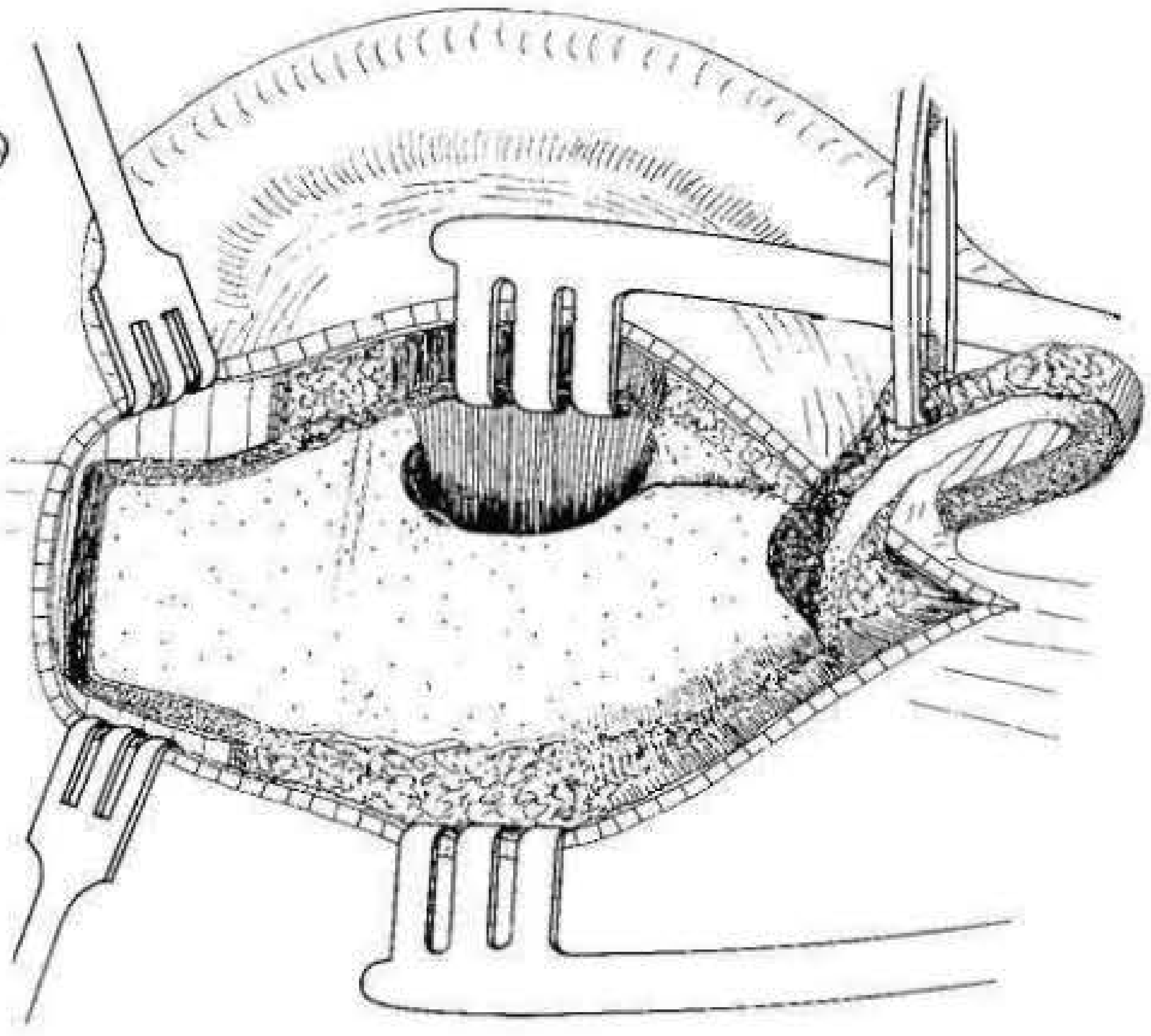


Fig. **963** The flap is completely elevated, exposing the entire mastoid process

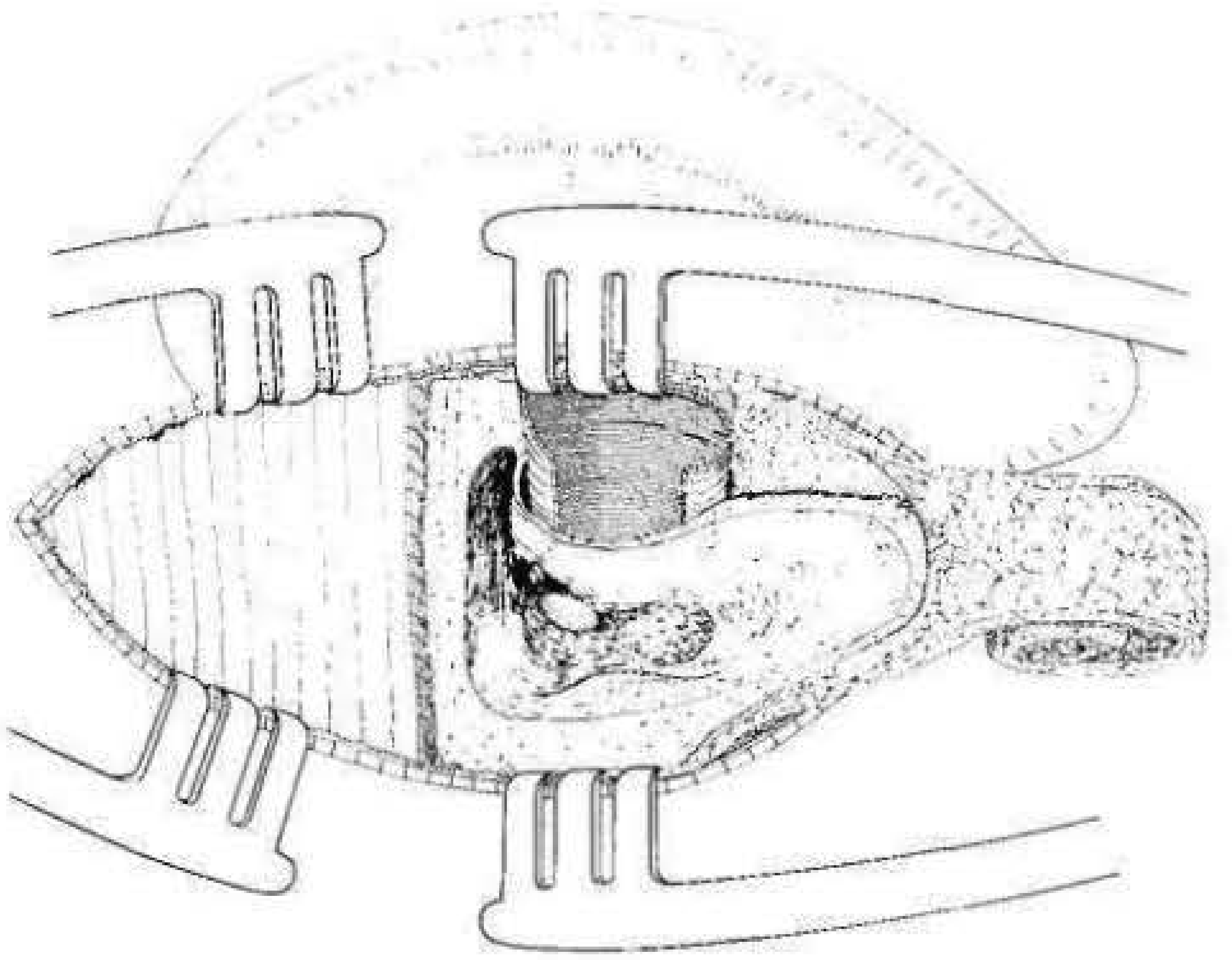


Fig. **964** An intact canal wall mastoidectomy is carried out

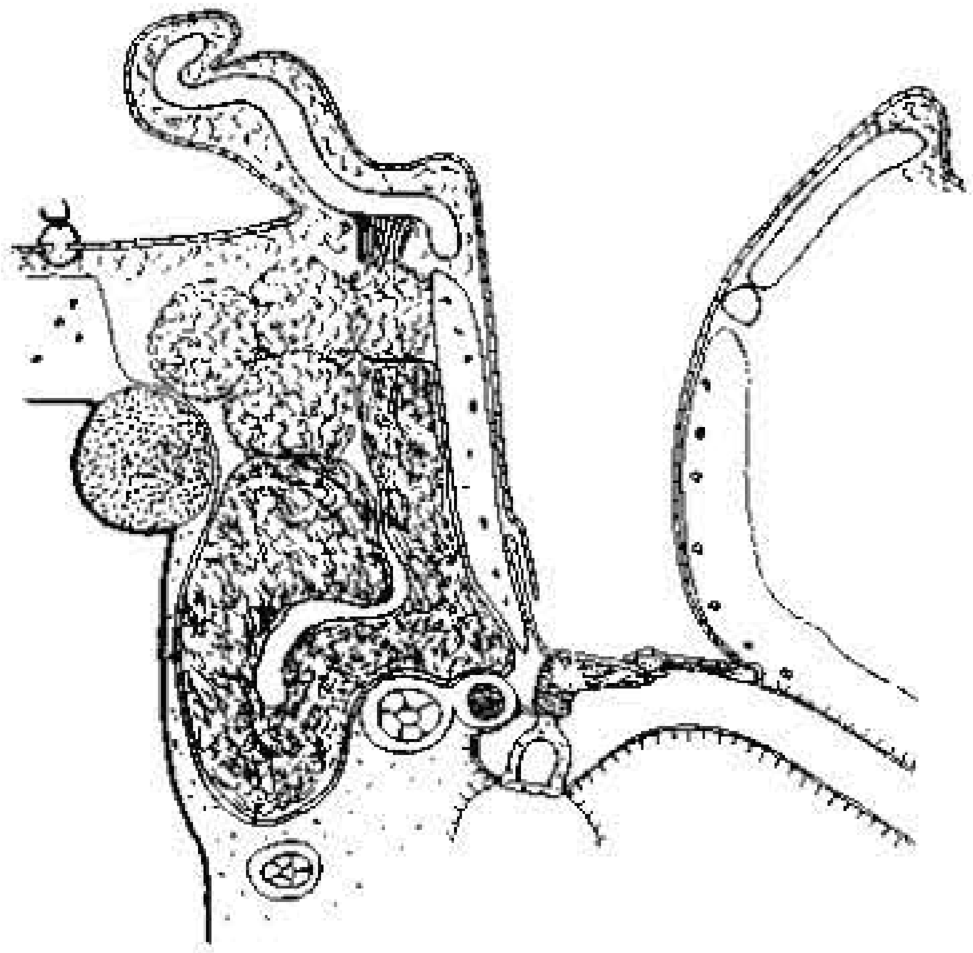


Fig. **965** **Side view of a Naumann obliteration in an intact canal wall mastoidectomy.** The flap occupies all the space within the cavity, especially at the tympanic isthmus region. An ossiculoplasty with a shaped incus is carried out. The fascia is placed on the bony ear canal and covered with a skin flap. Some Gelfoam is placed laterally in the cavity

Farrior Inferior Pedicled Flap

Using his own endaural approach (Vol. 1, pp. 28–30) Farrior (1962) introduced obliteration using a relatively large, inferiorly-pedicled flap containing the inferior part of the temporalis muscle and the postauricular muscle, as well as the fibrous tissue, periosteum, and muscles from the mastoid tip.

Using the Farrior incision, the laterally-based conchal skin flap is elevated. The subcutaneous tissue and the periosteum attached to the conchal skin flap are dissected, creating a conchal periosteum flap (Vol. 1, Figs. **58–60**). The conchal cartilage and conchal flap are retracted, exposing the subcutaneous tissue of the mastoid process (Fig. **966**). The temporalis muscle and the subcutaneous tissue, together with the periosteum, are elevated with a pair of scissors and cut first anteriorly, then superiorly, and finally posteriorly to the mastoid tip (Fig. **967**). An inferiorly-pedicled muscle–periosteum flap is developed (Fig. **968**), and is held aside during the mastoidectomy together with the conchal flap, by the posterior blade of the selfretaining retractor (Fig. **969**). The inferior part of the cavity is obliterated with the muscle flap, and the superior part is covered with fascia. The attic, aditus ad antrum, and part of the antrum remain as an open cavity. The ear canal skin is replaced, as is the conchal skin flap (Fig. **970**).

Some of the inferiorly-pedicled flap methods only obliterate the inferior part of the cavity, leaving the superior part, especially the attic and aditus ad antrum, as open cavities (Meurmann, Guilford, Farrior). Only methods involving large parts of the temporal muscle (Hilger and Hohmann, Naumann) can obliterate the cavity completely.

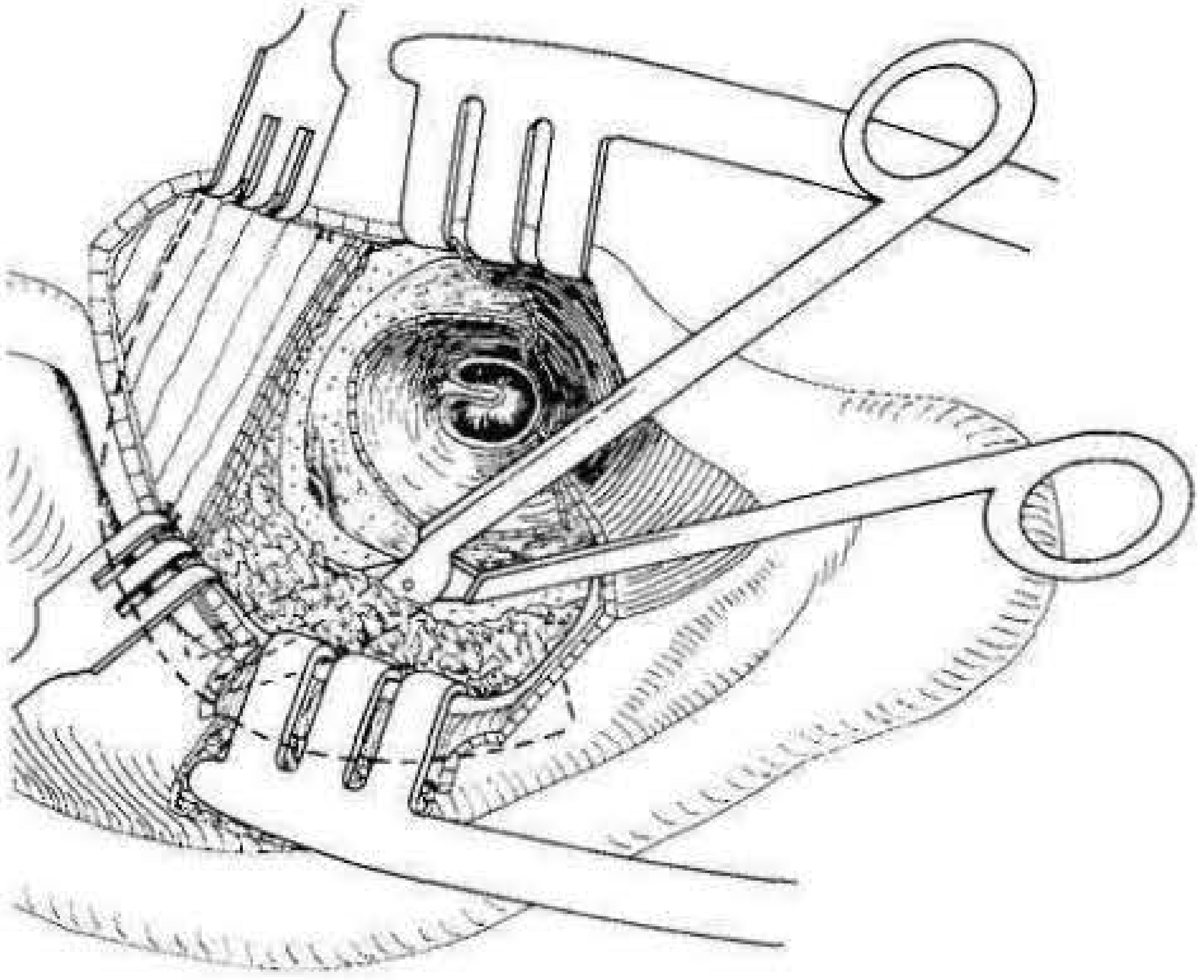


Fig. **966** **The Farrior inferiorly-pedicled flap.** In an endaural approach with the Farrior incision, the conchal skin flap and the conchal periosteal flap are developed and elevated. They are held back by the posterior blade of the selfretaining retractor. The size of the inferiorly-pedicled flap is indicated by the dashed line. The flap is elevated from the bone with a pair of scissors

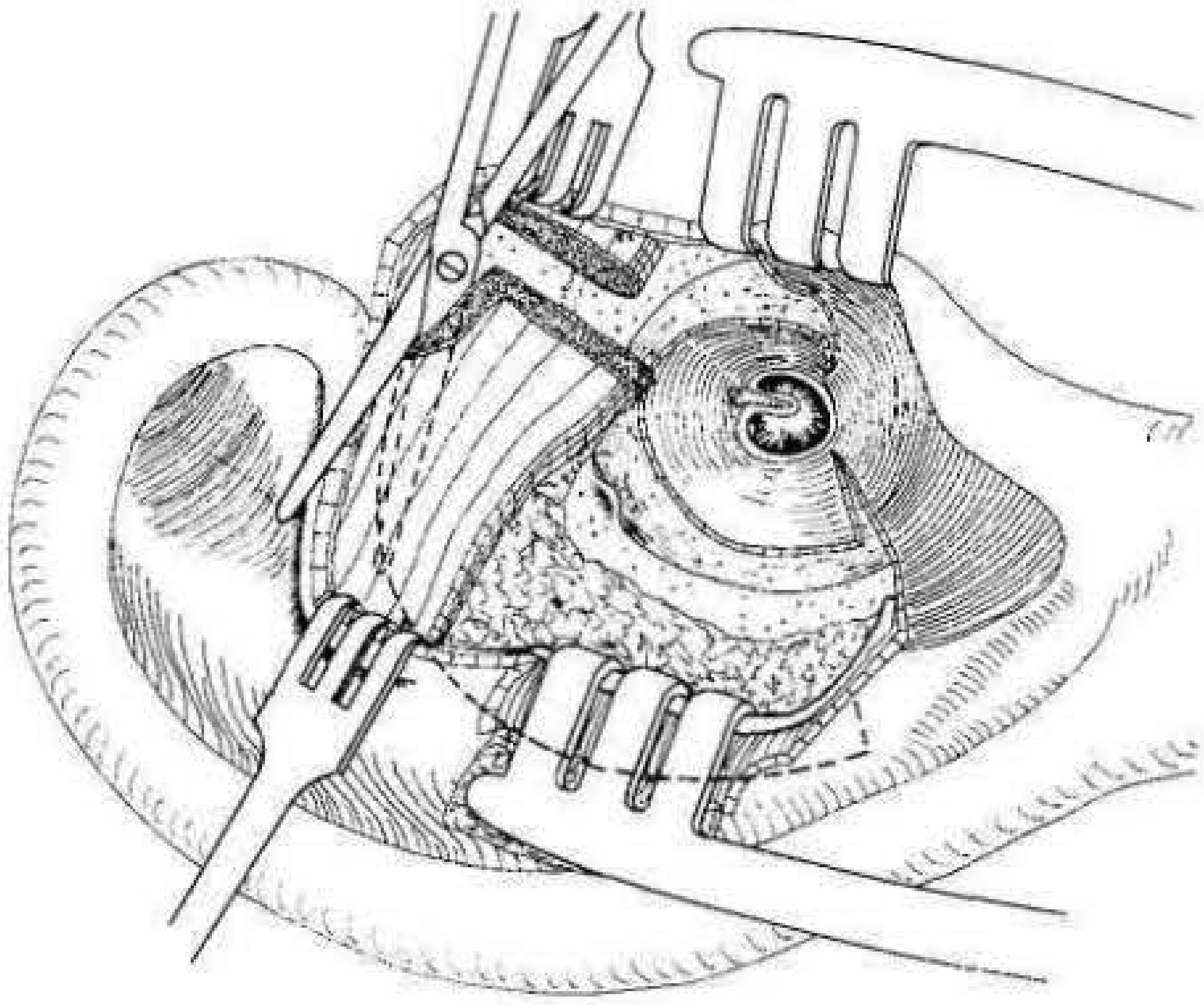


Fig. **967** The temporalis muscle is cut anteriorly, superiorly, and further down, along the dashed line

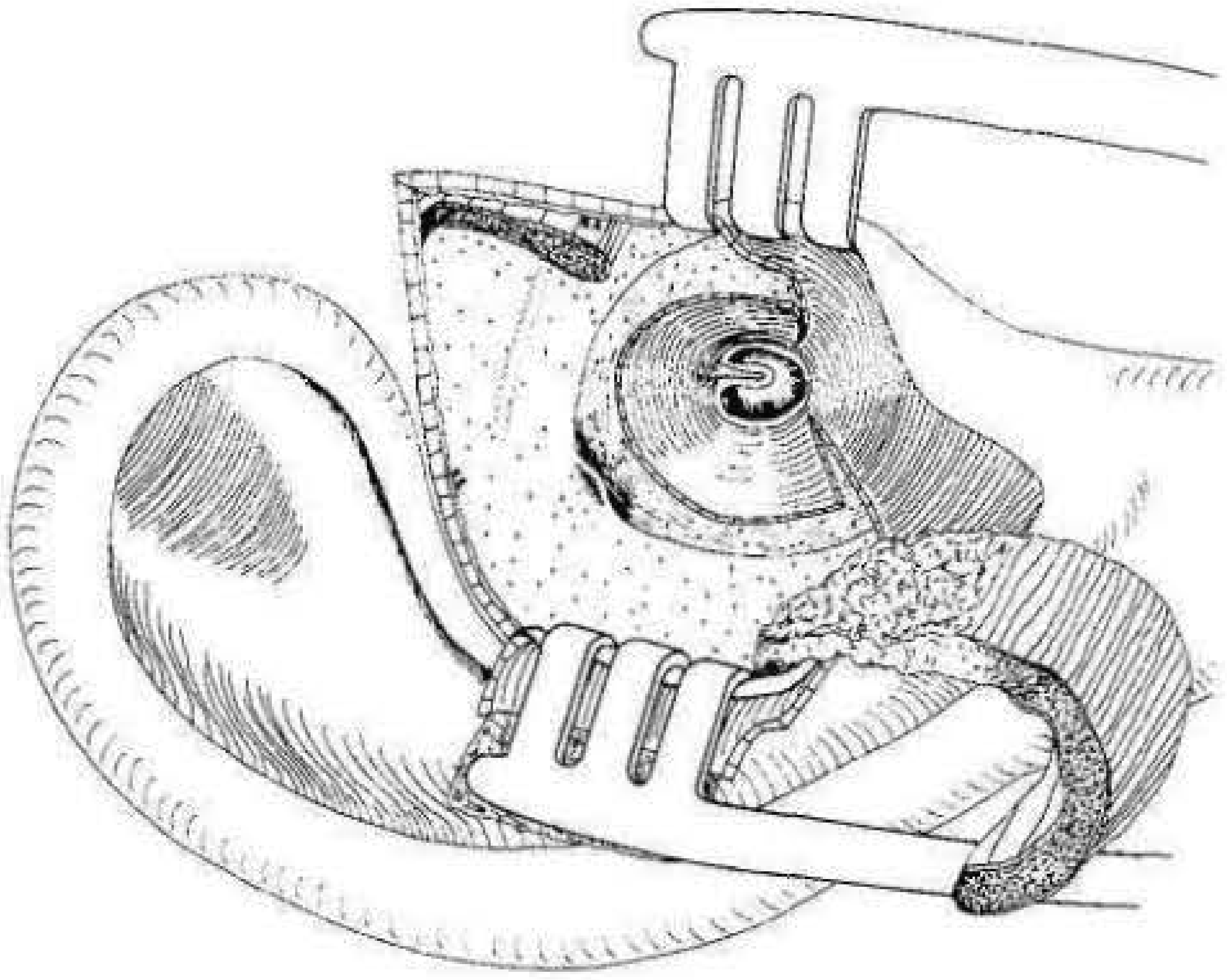


Fig. **968** The subcutis–muscle–periosteum flap is totally elevated, and the mastoid process is exposed

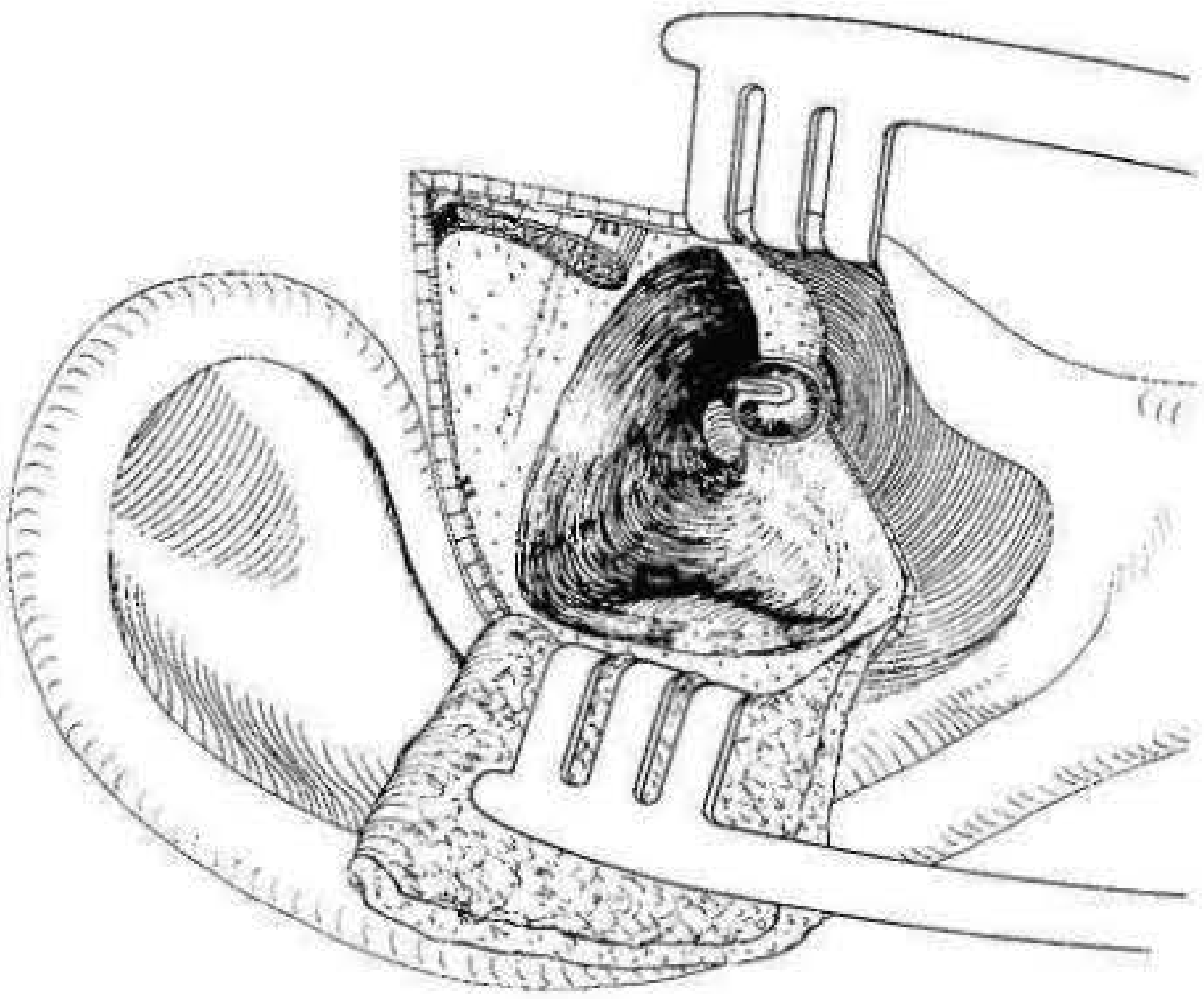


Fig. **969** The flap is held in place under the posterior blade of the selfretaining retractor. A canal wall–down mastoidectomy is performed. The ear canal skin is removed

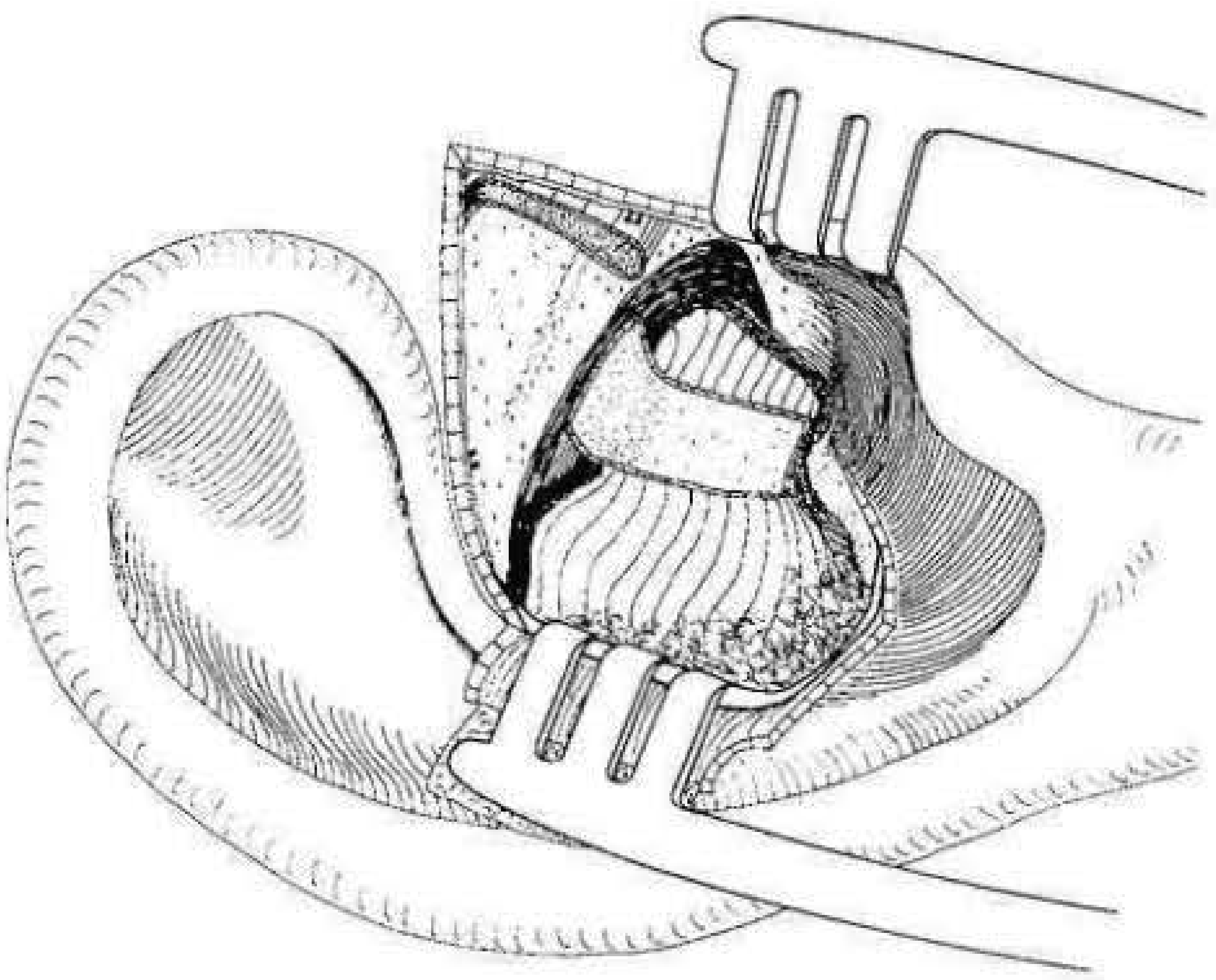


Fig. **970** The flap is placed in the inferior part of the cavity. The superior part of the cavity, with the perforation, is covered with a fascia graft, and the free ear canal skin flap covers the fascia, muscle, and bone

Complications

Although obliteration creates bleeding from the muscle and subcutaneous tissue during the cutting of the flap, disturbing microsurgery, very few complications related to the muscle flaps have been reported.

Bleeding. Bleeding from the auricular branches of the superficial temporal artery has to be coagulated with bipolar diathermy in flap methods involving the temporal muscle. Superoanteriorly pedicled temporalis muscle flaps (Table **12** do not usually bleed, because the arterial supply is included in the pedicle.

Flaps involving retroauricular fibrous tissue (Tables **12**, **13**) may bleed from the emissary vein of Santorini at the mastoid foramen, located behind the mastoid process near the occipitomastoid suture (Fig. **52**). If diathermy is not sufficient, packing using Surgicel, or even bonewax may be necessary. A small separate skin incision at the mastoid foramen, rather than further elevation of the skin, makes hemostasis easier.

Bleeding from the divided muscle fibers of the splenius capitis, transversus nuchae, and longissimus dorsi muscles, supplied by the occipital artery, can be stopped by compression.

Bleeding can occur during preparation of the Palva flap, particularly anteriorly, near the concha. Later, bleeding can occur from the auricular branches of the stylomastoid artery, and is easy to coagulate. Anterior bleeding is annoying, because the blood runs into the middle ear, disturbing the microsurgery. Even small bleeders therefore have to be coagulated. At the end of the operation, whilst trimming a large Palva flap (Figs. **935**, **937**), bleeding is again disturbing, and the cavity should be filled with gauze during this procedure. The gauze is taken out just before pushing the flap into the empty cavity.

Bleeding from the flap after placement in the cavity ceases after packing of the ear canal. The canal is thus somewhat dilated, and the flap is pushed posteriorly (Figs. **892**, **940**, **941**).

Hematoma. Hematoma requiring evacuation by aspiration can occur at the site of the harvesting of the temporalis muscle, but this is rare. The temporalis muscle region must be inspected before external dressings are applied and before the patient wakes from general anesthesia. The external packing is removed after 24 hours.

Infections. Infections may occur, but are extremely rare. Abscess requiring incision in the temporal region has been described. We use peroperative prophylactic penicillin treatment of 2 million units intravenously, continuing with tablets of 1 million units three times daily over four days, but many other prophylactic treatment modalities are used.

Flap necrosis. Flap necrosis has been observed. It is extremely rare. The necrotic part of the flap can be trimmed through the ear canal.

Granulations. Granulations can appear between the graft junctions and between the incisions for the ear canal widening. They have to be

Table **13** **Superiorly based flaps**

Author	Approach	Consists of	Basis	Comment
Rambo (1957)	Endaural	Temporalis muscle	Supero-anterior	Short, mainly tympanic cavity
Thorburn (1961)	Endaural	Temporalis muscle	Supero-anterior	Prolonged by fascia
Guilford (1961)	Endaural + retroauricular	Retroauricular SMP tissue	Superior	Two approaches
Freerich and Williams (1962)	Endaural	Temporalis muscle	Supero-anterior	Short
Elbrønd (1963)	Endaural + retroauricular	Retroauricular SMP tissue	Superior	Two approaches
Tos (1969)	Retroauricular	Temporalis muscle + retroauricular SMP tissue	Supero-anterior	Bipartite. Ear canal reconstruction
Turner (1966)	Endaural + retroauricular	Temporalis muscle	Supero-anterior + supero-posterior	Two flaps. Extensive surgery
Withcher and Streit (1963)	Endaural	Temporalis muscle	Supero-anterior	Tripartite. Ear canal reconstruction
Dawlatly (1992)	Retroauricular	Temporalis muscle	Supero-posterior	Pedicled fascia
East etal. (1991)	Retroauricular	Large fascia with vessels	Supero-anterior	Only fascia

SMP: subcutis–muscle–periosteum

Table **14** **Anteriorly and inferiorly based flaps**

Author	Approach	Consists of	Basis	Comment
Moscher (1911)	Retroauricular	Retroauricular SMP tissue	Antero-superior	In simple mastoidectomy
Palva (1962)	Retroauricular	Retroauricular SMP tissue	Anterior	Ear canal reconstruction
Meurman and Ojala (1949)	Retroauricular	Retroauricular SMP tissue	Infero-posterior	Fixed by suture
Meurman and Ojala (1949)	Endaural	Retroauricular SMP tissue	Infero-posterior	Fixed by suture
Guilford (1960)	Endaural + retroauricular	Retroauricular SMP tissue	Infero-posterior	Fixed by suture. Two approaches
Hilger and Hohmann (1962)	Retroauricular	Temporalis muscle + retroauricular SMP tissue	Inferior	Large flap
Naumann (1966)	Endaural + retroauricular	Temporalis muscle + retroauricular SMP tissue	Inferior	Large flap + intact canal
Farrior (1962)	Endaural	Temporalis muscle + retroauricular SMP tissue	Inferior	Only inferiorly based

SMP: subcutis–muscle–periosteum

removed by forceps, and are seen three weeks after surgery following removal of the ear canal package.

Ear canal stenosis. Ear canal stenosis has been relatively frequently seen in the Rambo and the Freerich techniques, using large, anterosuperiorly pedicled temporalis muscle. The risk of ear canal stenosis — relative or absolute — is present in any mastoidectomy, but is more common in obliteration techniques, usually because the ear canal has not been widened at all, or not been widened enough.

With more than 30 years' experience with various obliteration techniques, and from analysis of the late results (10–20 years after operation) it is the present authors' strong opinion that ear canal widening is necessary in obliteration. However, a Heermann B incision at the 12-o'clock position either with or without small resection of the conchal cartilage, is usually enough in cases with a small cavity. In cases with a large cavity and small muscle flaps, a regular meatoplasty with major resection of the conchal cartilage, as described in Chapter 15, is necessary. Special care should be taken to avoid the widened ear canal becoming stenotic during the postoperative period. Packing of the ear canal is necessary until complete healing of the Heermann B incision has taken place. This may be up to two months after the operation.

During the first year, some enlargement of the cavity takes place, creating a relative stenosis of the external meatus, especially in cases with insufficient widening initially.

Combinations of Pedicled Subcutis Muscle Obliteration Techniques

This Chapter has gone into considerable detail — maybe beyond the scope of this book — and nearly all the methods published before and during the 1960s are described, some being adapted to modern concepts of mastoidectomy, without changing the original concept of the obliteration. The author believes that pedicled autogenous tissue from around the mastoid process is by far the best obliterative material, and all the methods described, or at least their basic concepts, can be applied to harvest the necessary grafts. Every method contains some good elements, and will sometimes be required to solve a particular cavity problem. Even when other obliteration methods, with bone chips, bone paté, cartilage allograft or biocompatbile materials, are used, an autogenous muscle graft will always be needed between the canal skin and the obliteration material in order to facilitate the migratory characteristics of the canal skin.

Because of risk of AIDS, allogenous tissues cannot be used in many countries, the demand for autogenous tissues, particularly muscle, has increased.

If autogenous obliteration flaps alone are preferred, then it is evident that total obliteration of a large cavity cannot be provided with a Palva flap, for example, alone. Other flaps are needed to fill the mastoid tip and posterior parts of the cavity. Therefore *additional tissue* has to be harvested from the temporalis muscle and turned down as superoanteriorly pedicled, or even better as superoposteriorly pedicled, flaps (Table **13**). Some improvisation is always needed when harvesting such combined flaps, depending on the original approach, the size of the skin incision, and the availability of a particular type of tissue.

With extensions of the cavity deep into the mastoid tip, an additional inferiorly-pedicled flap is needed (Table **14**). Inferiorly pedicled flaps are also needed to obliterate the posterior part of the cavity.

The concept used in the Meurmann, Farrior and Guilford flaps (Table **14**) — obliterating the inferior part of the cavity and leaving the attic and aditus ad antrum as an open cavity, without reconstructing the ear canal — is a safe method, and one that is often used. In fact, none of the inferiorly-pedicled flaps can reconstruct the ear canal. Only the Palva and Tos methods include total reconstruction of the ear canal.

Some obliterated ears result in a cavity after several years. Epithelial lining of such a cavity is much better than lining an open cavity with the epidermis lying directly on the bone. Muscle flaps carry blood supply to the epithelial lining, and the selfcleaning of such a cavity is usually good. The flap tissue covering the bone after retraction and atrophy will cover small irregularities of the cavity wall, making it smooth and easy to clean mechanically, especially if the ear canal is wide enough and the facial ridge is low.

19 Cavity Obliteration with Cartilage

Autogenous tragal or conchal cartilage was introduced into tympanoplasty by Utech (1961), Goodhill (1961), Guilford (1961), Farrior (1962), Heermann (1963), Heermann and Heermann (1964), Goodhill (1967), McCleve (1969); and cartilage from the nasal septum was introduced by Salen (1963).

Allogenous cartilage has been used from the nasal septum (Jansen 1963), knee (Wehrs 1972) and rib (Maffei and Zini 1972, Cole 1992, Zini 1994). Hagerty (1967) implanted both viable and nonviable cartilage allografts into human volunteers, and found no significant inflammatory reaction, even after six years. Implanted cartilage becomes fibrotic after some years, mainly because of fibrous degeneration and resorption of the cartilage (Steinbach and Pusalkar 1981). A cavity obliterated mainly using allogenous cartilage will therefore become larger for some years following the obliteration.

Autogenous Cartilage

Even if the largest possible pieces of conchal and tragal cartilage are harvested (Vol. 1, Chapter 6) the amount of autogenous cartilage is not alone sufficient to completely obliterate a large cavity. Obliteration using autogenous cartilage therefore usually result in a combined-graft obliteration. Nevertheless, autogenous cartilage is often used in various ways in the reconstruction of the ear canal wall, as well as in obliteration of the cavity. The many methods of using cartilage that are described are basically applied in two different situations: obliteration of the cavity in canal wall–up mastoidectomy, and obliteration in canal wall–down mastoidectomy.

Obliteration in Canal Wall–Up Mastoidectomy

In any modern obliteration of the mastoid cavity, the obliteration procedure has to be combined with a reconstruction of the posterior ear canal wall, or with a meatoplasty, or with both. If obliteration is desired in classic canal wall–up mastoidectomy (Chapter 6) or in the Tos modification of the canal wall–up mastoidectomy (Chapter 7), the bony ear canal will be more or less intact, and usually only small defects will need to be reconstructed in association with the obliteration. For these procedures, autogenous tragal and conchal cartilage are the ideal materials, not only for reconstruction of ear canal wall defects, but also for obliteration of the attic and aditus ad antrum. Any remaining parts of the cavity can be obliterated with other materials, resulting in obliteration by a combined graft. In other modifications of canal wall–up mastoidectomy, such as the Wigand (Chapter 9) and Farrior techniques (Chapter 10) obliteration behind the preserved ear canal wall or the bridge can be performed using autogenous cartilage.

In the following situations, cartilage forms an important part of the obliteration:

1. *Complete primary obliteration of the cavity after classic intact canal wall mastoidectomy* (described in Chapter 6, Figs. **381–383**). Usually, there is a defect in the bony ear canal wall requiring a rigid scutumplasty using cartilage and firm obliteration of the attic behind the scutumplasty and intact ear canal wall. A combination of autogenous cartilage graft, Palva flap, bone chips, and boné paté is sometimes necessary (Figs. **381–383**). In cases with a completely intact ear canal wall, obliteration of the attic and aditus using autogenous cartilage is carried out (Fig. **971**), and the rest of the cavity is obliterated with muscle, usually in the form of a Palva flap (Fig. **972**). Meuser (1993) uses pieces of allogenous rib cartilage to obliterate the cavity after intact canal wall mastoidectomy, but only in cases where one is confident of complete exenteration of the cholesteatoma. Larger pieces of cartilage are placed medially in order to close the attic and to reconstruct the scutum defect if possible. Finally, smaller rectangular pieces of cartilage are used to obliterate the lateral part of the cavity. Meuser uses an endaural approach in intact canal wall mastoidectomy procedures, although the retroauricular approach is the one more commonly used (Fig. **973**).
2. *Complete obliteration of the cavity as a second-stage procedure* after classic canal wall–up mastoidectomy, still preserving part of the posterior bony ear canal wall, and reconstructing with a scutumplasty (Yanagihara et al. 1993, Gyo et al. 1992). First, the scutumplasty is performed using tragal cartilage, and obliteration is then carried out

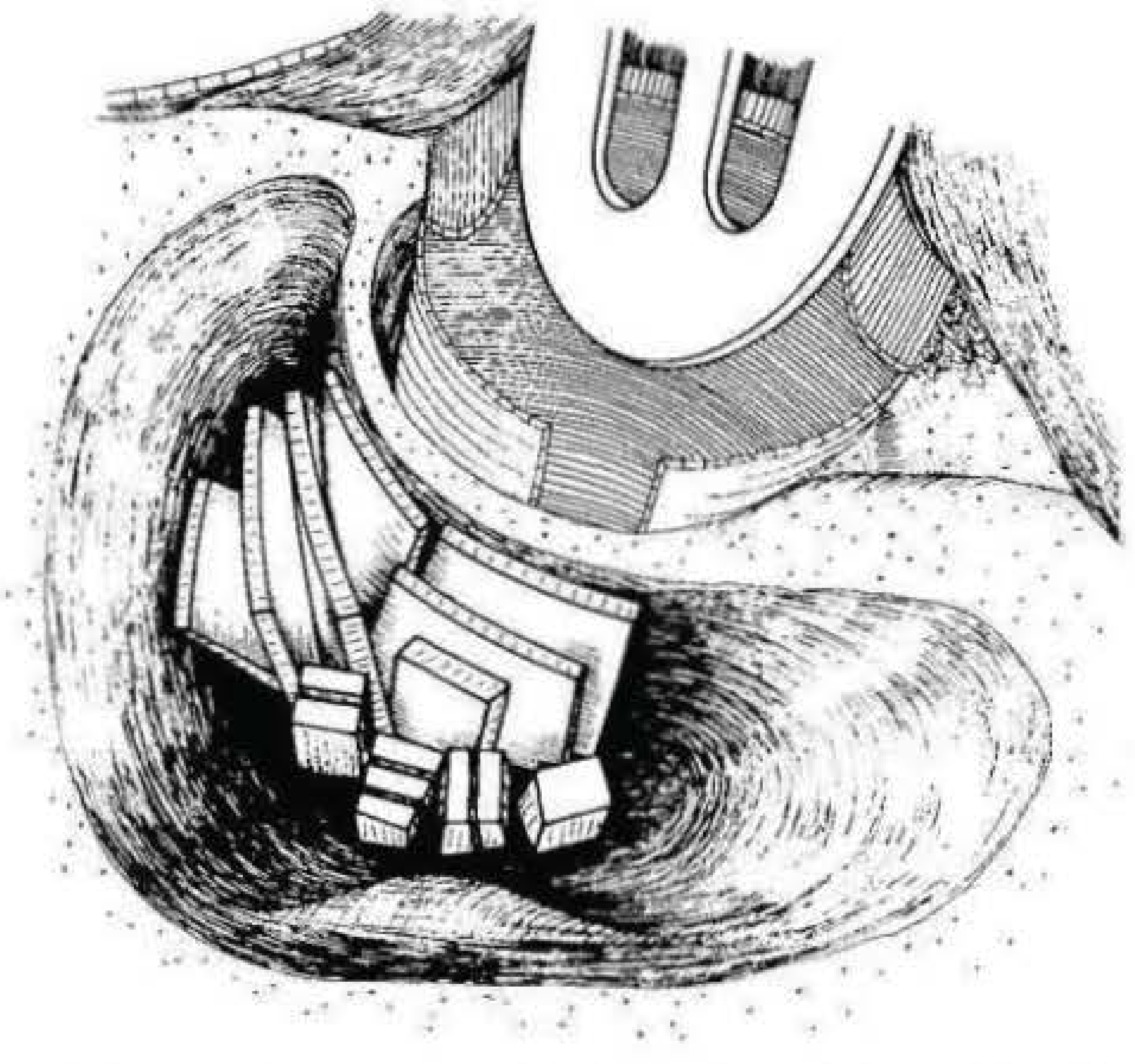


Fig. **971** **Primary total obliteration of the cavity after classic intact canal wall mastoidectomy using autogenous cartilage and a Palva flap.** After a canal wall–up mastoidectomy with a completely intact ear canal wall, plates of tragal cartilage are placed on the medial attic wall behind the intact ear canal wall to form a close and tight connection with the tympanic cavity. Behind these plates, other pieces of available cartilage tightly obliterate the attic, antrum, and the medial part of the cavity. The lateral part of the cavity will be filled with a muscle flap

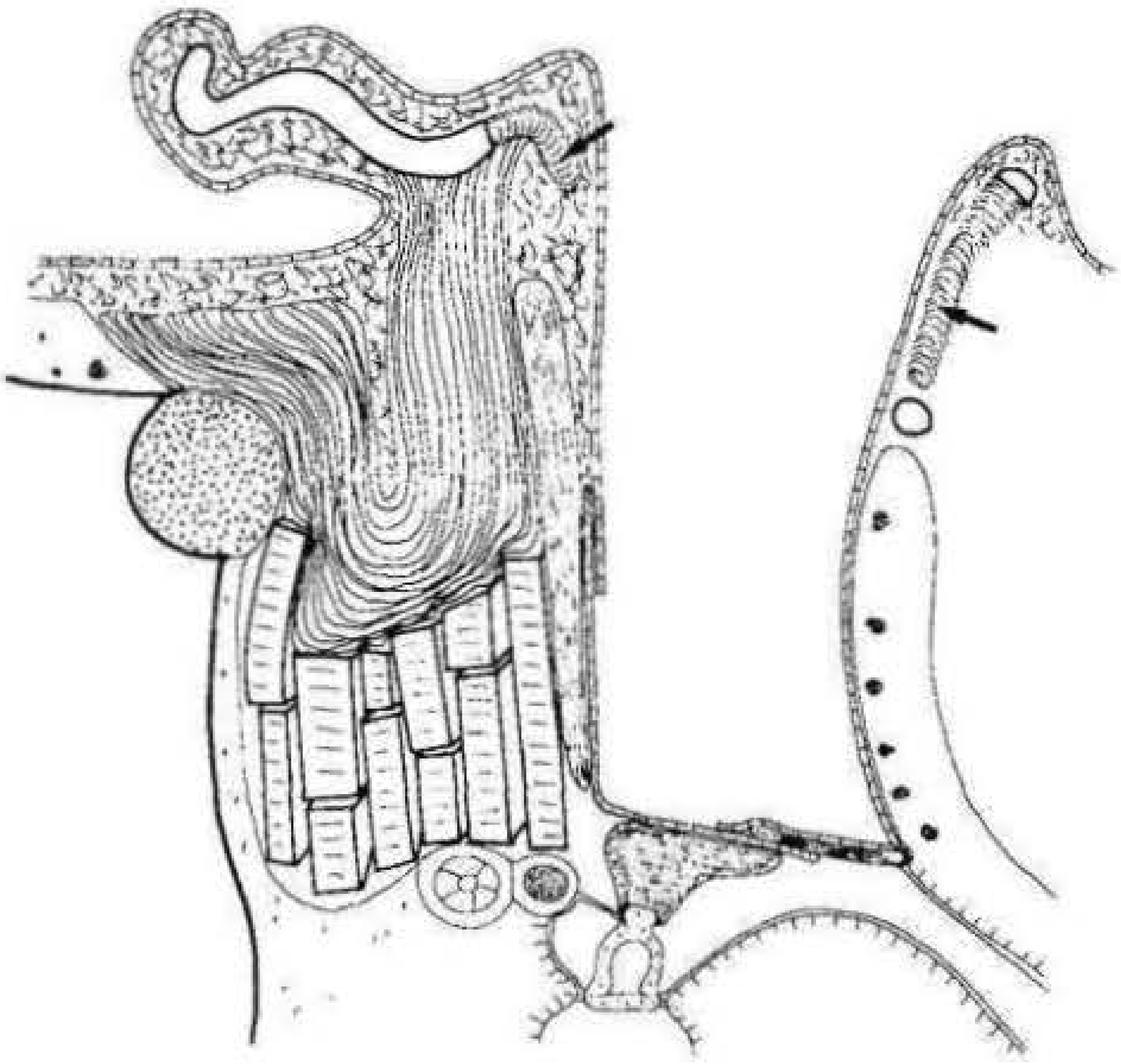


Fig. **972** Side view of the obliteration with autogenous tragal and conchal cartilage and Palva flap behind an intact bony ear canal wall. The cartilage obliterates the medial part of the cavity; the lateral part is obliterated with a Palva flap. A piece of cortex is shaped and placed between the stapes and malleus handle. The posterior perforation is closed with an underlay fascia graft, continuing over the bony ear canal wall. The resected parts of the cartilage are indicated by arrows

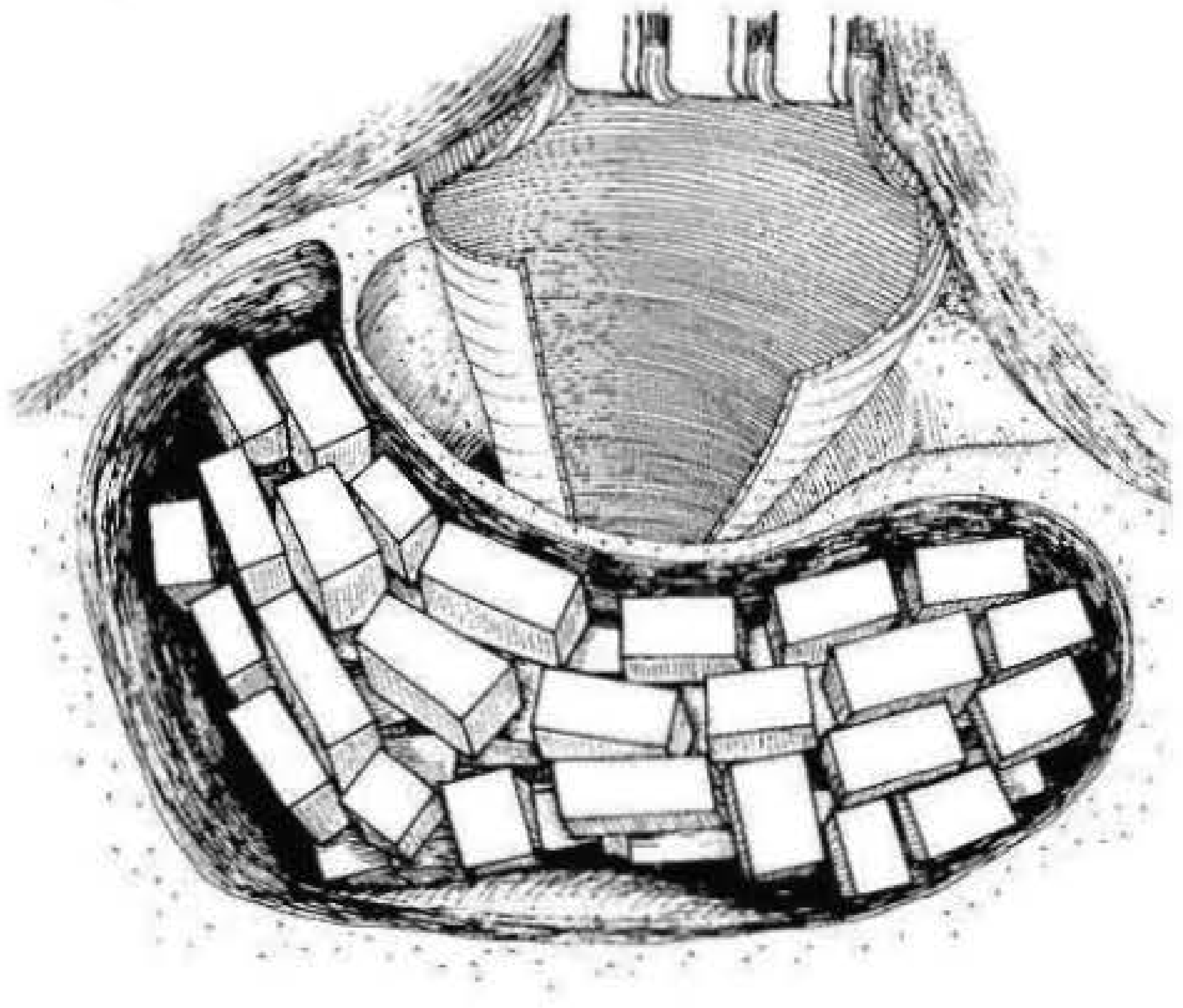


Fig. **973** **Obliteration, using allogenous costal cartilage** (Meuser), of the mastoid cavity behind an intact canal wall. Many small rectangular pieces of costal cartilage are placed in the cavity to completely fill it

behind the cartilage, using a Palva flap and hydroxyapatite blocks (Fig. **384**) — again as a combined-graft procedure.

3. *Partial cavity obliteration in classic canal wall–up mastoidectomy* (Fig. **192**). In addition to scutumplasty with cartilage, further cartilage plates are used to separate the attic from the antrum, which is obliterated with bone paté mixed with fibrin glue (Figs. **385, 386**). The ear canal remains intact, and the attic is ventilated, whilst the rest of the cavity is obliterated (Honda 1992).

4. *Complete obliteration in certain situations using the Tos modified canal wall–up mastoidectomy.* In ears with no remaining ossicles in the attic, an absent bony bridge, and extensive resorption of the posterior attic wall, the risk of retraction is great (Fig. **477**). In such cases, obliteration of the cavity behind the preserved ear canal wall may therefore be desirable. A large piece of tragal cartilage placed over the facial eminence covers the ear canal defect, and closes the attic completely. Several pieces of tragal or conchal cartilage or bone can be placed behind the tragal cartilage, thus firmly obliterating the cavity. The lateral wall of the cavity is obliterated with a Palva flap (Fig. **974**), again as a combined-graft procedure.

5. *Complete obliteration in cases of temporary removal of the ear canal using Feldmann's technique* (Chapter 8) (Feldmann 1977, 1978) After replacement of the posterior bony ear canal wall, Mercke (1987) totally obliterates the cavity using bone chips (Figs. **523, 524**). In this type of situation, the present author prefers to use autogenous conchal and tragal cartilage, as indicated in Figure **974.**

6. In *Farrior's atticotympanotomy and mastoidectomy technique* (Chapter 10, Fig. **552**), obliteration of the separate mastoid cavity is often desired, due to the high risk of retraction. As well as obliteration using cartilage and bone (Fig. **561**), autogenous cartilage alone or in combination with muscle is recommended (Fig. **975**).

Autogenous cartilage has also been used for reconstruction of the ear canal wall in many *other situations:*

A. Scutumplasty in classic intact canal wall mastoidectomy (Figs. **349–359**) (McCleve 1969, 1985, Fleury 1974, Adkins and Osguthorpe 1984, Hildmann 1991, Kinney 1982, Honda 1992, Sheehy 1990, Portmann 1979, Choissone 1985, Linde 1973, Eviatar 1978).

B. Reconstruction of atticotomies in the modified intact canal wall technique (Chapter 7), either with an intact bridge (Fig. **440**), a defective bridge, or a displaced and missing bridge (Fig. **478**).

C. Ear canal wall reconstruction in Wigand's technique (Chapter 9), with cartilage covering the atticotomy and antrotomy openings (Figs. **546, 548** to **551**).

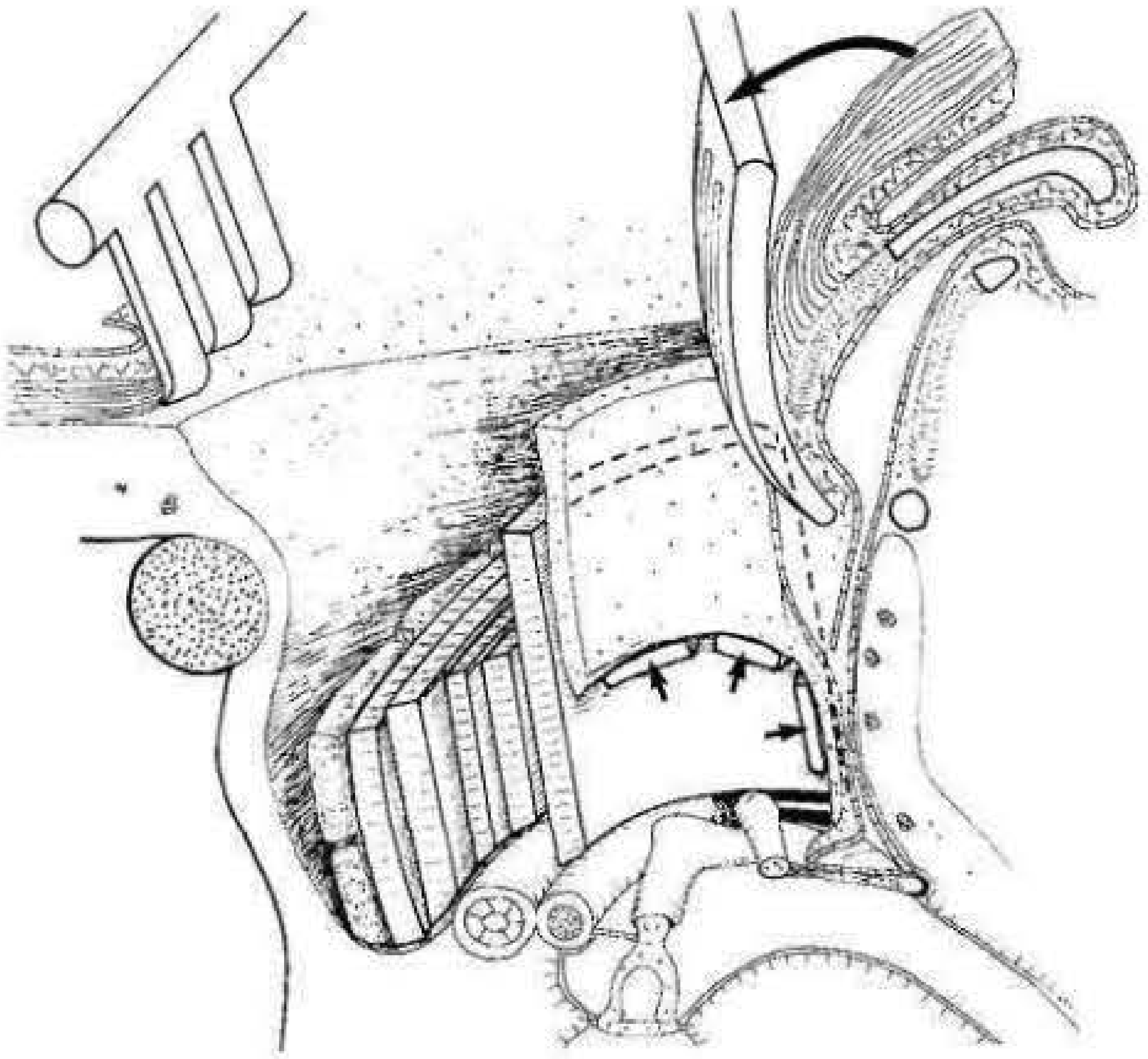


Fig. **974** Side view, with some perspective, of combined-graft obliteration of a cavity after modified intact canal wall mastoidectomy with a large defect in the bony ear canal wall. A large plate of cartilage is placed on the medial wall of the attic, behind the bony ear canal wall. Several small pieces of cartilage support the tragal cartilage and obliterate the attic and aditus. Pieces of bone or bone chips are placed behind the cartilage, and the lateral part is obliterated with a Palva flap, which is ready to be placed in the cavity after removal of the selfretaining retractor (large arrow). At the border between the ear canal and the cartilage, additional small pieces of cartilage are placed to tighten the fissures between the bone and cartilage (small arrows)

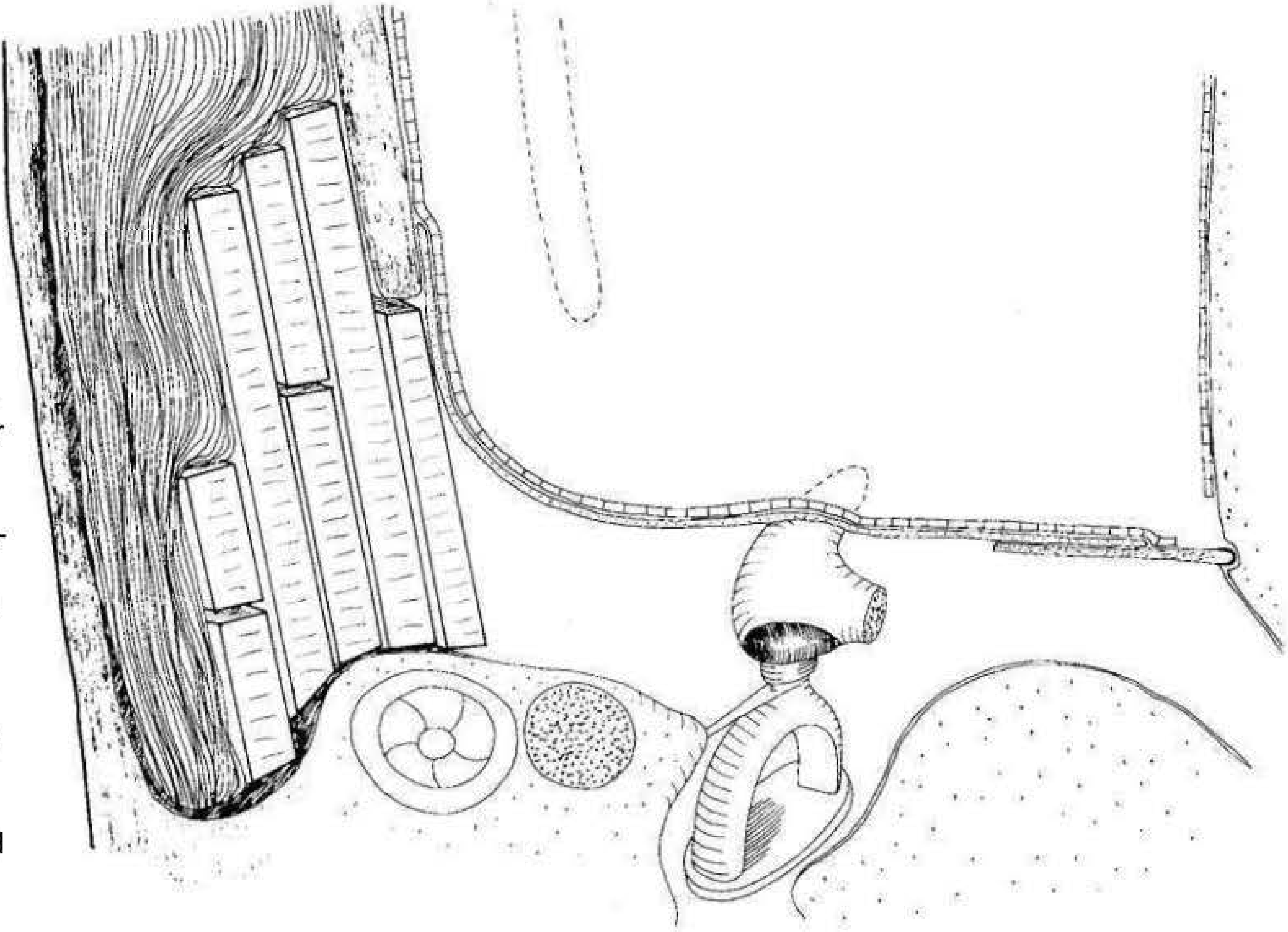


Fig. **975** Obliteration of the posterior part of the cavity behind a displaced bony ear canal wall, following Farrior's technique. The original position of the ear canal wall is indicated with cashed lines. The attic is ventilated, and is covered with a large fascia. Behind the preserved and displaced bony ear canal wall, the cavity is obliterated with pieces of autogenous cartilage and muscle

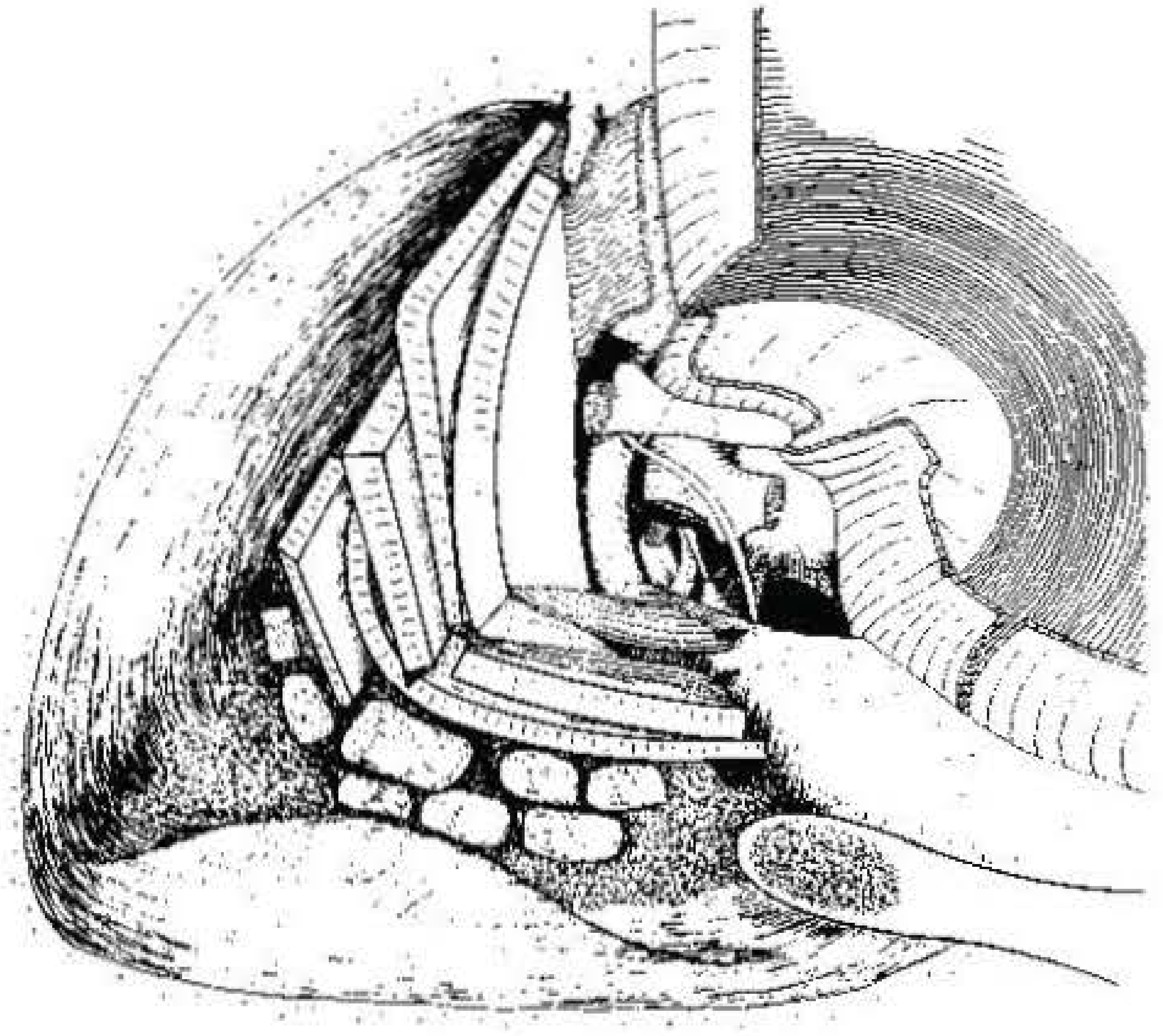


Fig. **976** **Combined-graft obliteration** (Tos) in a canal wall–down mastoidectomy cavity with reconstruction of the ear canal wall with tragal cartilage. A large piece of tragal cartilage is placed on the medial wall of the attic as a compound graft. The attached perichondrium is placed on the zygomatic root and facial ridge (arrows) to secure the position of the cartilage and tighten the new ear canal wall. Further pieces of tragal or conchal cartilage are placed behind the tragal cartilage. The deepest part of the cavity is covered with pieces of bone, bone chips, and bone paté. The lateral part of the cavity will be filled with muscle

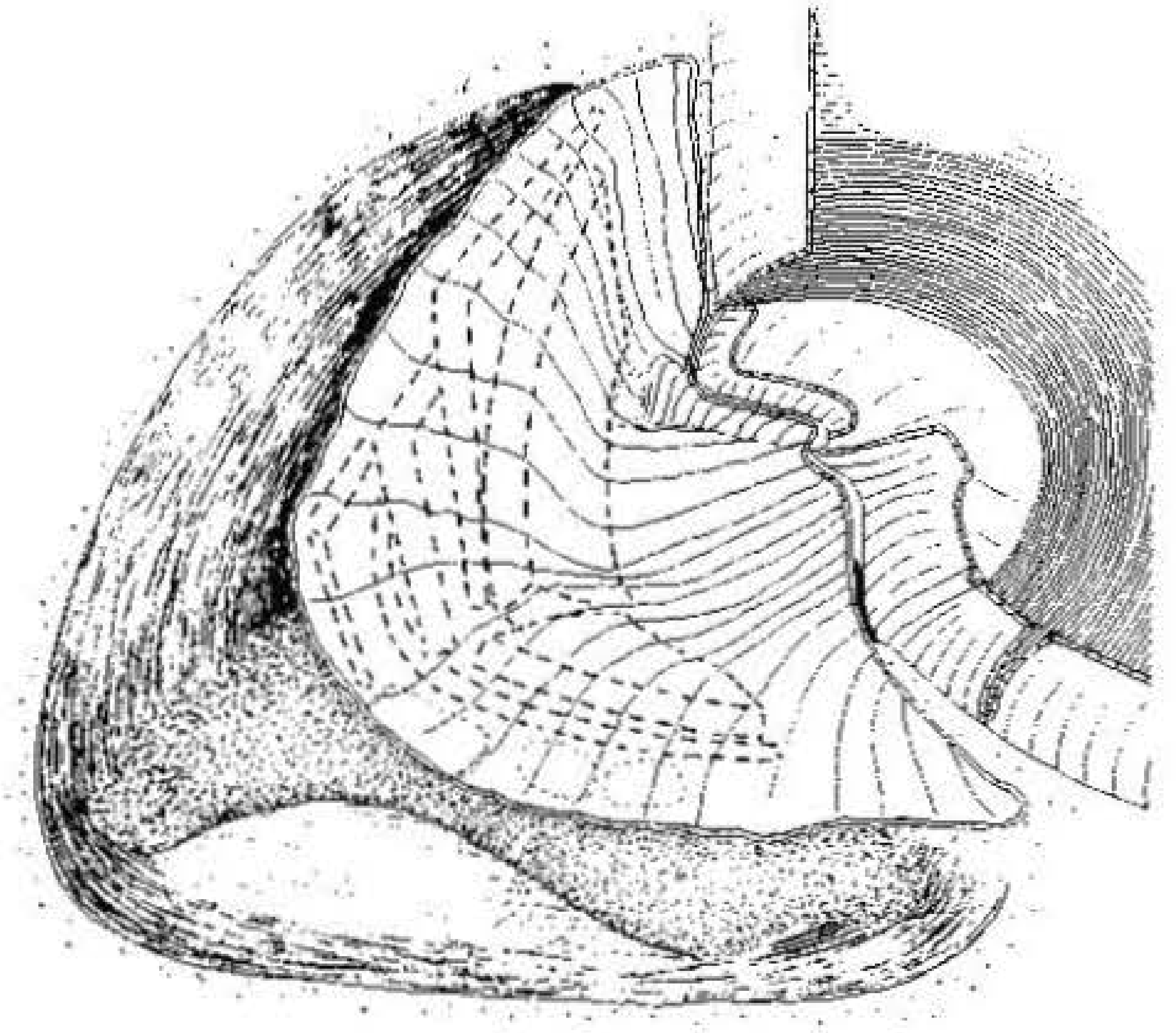


Fig. **977** The fascia covers the posterior perforation as an underlay graft, as well as the entire reconstructed ear canal wall. Bone paté is visible in the sinodural angle and the mastoid tip

D. Closure of the aditus ad antrum in "antrum exclusion, attic elimination on demand techniques" (Olaizola 1988) (Fig. **563, 565, 567**).

E. Reconstruction of the entire ear canal wall with autogenous cartilage in order to ventilate the cavity (Chapter 17, Figs. **824–831**).

Obliteration in Canal Wall–Down Mastoidectomy

As mentioned above, autogenous tragal and conchal cartilage do not totally obliterate a large cavity. They form either 1) part of a combined-graft total obliteration in large cavities; 2) obliterate only part of the cavity, in combination with an adequate meatoplasty (Heermann 1992); or 3) obliterate parts of the cavity, which basically remains an open one.

Autogenous Cartilage in Combined-Graft Obliteration

As in obliteration with combined grafts in canal wall–up techniques (Figs. **971–975**), the plates of autogenous cartilage are used for the most medial part of the ear canal wall reconstruction, simply because the tragal cartilage fits into the attic well and provides a smooth and firm medial boundary to the new ear canal wall.

The author has performed reconstruction of the ear canal using autogenous tragal cartilage in combined-graft obliteration (Tos 1977, Siim and Tos 1987, 1989). After a canal wall–down mastoidectomy with preservation of as many ear canal skin flaps as possible, ossiculoplasty is performed (Fig. **976**). A large piece of tragal cartilage with attached perichondrium is placed on the medial wall of the attic at the border between the facial nerve eminence and the lateral semicircular canal. The tragal cartilage forms the posterosuperior ear canal wall, and adjacent conchal and tragal cartilage fixes it to the anterior cavity wall. All remaining tragal and conchal cartilage is placed in smaller pieces behind the large tragal cartilage graft, thus obliterating the attic and closing all the fissures between the cartilage and the cavity walls. Behind the autogenous cartilage, bone paté is placed in the deepest part of the cavity, e. g., into the sinodural angle or into the mastoid tip, or both, and pieces of autogenous cortical bone and bone chips are then placed behind the cartilage (Fig. **976**). Once the cavity has been partly obliterated, the remaining reconstruction of the ear canal and the myringoplasty are completed by placing a large, specially tailored piece of "semidry" temporalis muscle fascia as an underlay graft, closing the ear drum perforation, and covering the interposed ossicle and the entire meatal surface of the tragal cartilage. Superiorly, the fascia is placed on the zygomatic root, and inferiorly onto the facial ridge (Fig. **977**). The medial ear canal skin flaps are replaced and fixed using Gelfoam balls (Fig. **978**) or small pieces of gauze, or both.

The obliteration of the lateral part of the cavity (Fig. **978**) is performed using a superiorly-based bipartite subcutis–muscle flap (Tos 1969) (Figs. **881–890**). In reconstruction of the lateral part of the cavity, a small Palva flap is also used (Figs. **821, 831, 974**). The bipartite temporalis muscle can be placed in the lateral part of the cavity without loosening the selfretaining retractor (Fig. **978**). The small Palva flap is used at the very end of the operation, after widening of the ear canal with an intercartilaginous incision at the 12-o'clock position, and extending 1–2 cm vertically, anterior to the helix (Fig. **979**).

The small Palva flap ensures a tight connection between the epithelial flap (the Kroner flap) and the fascia, which is often shorter than desired.

Another type of obliteration uses a large Palva subcutis–muscle flap (Fig. **980**). The Palva flap is

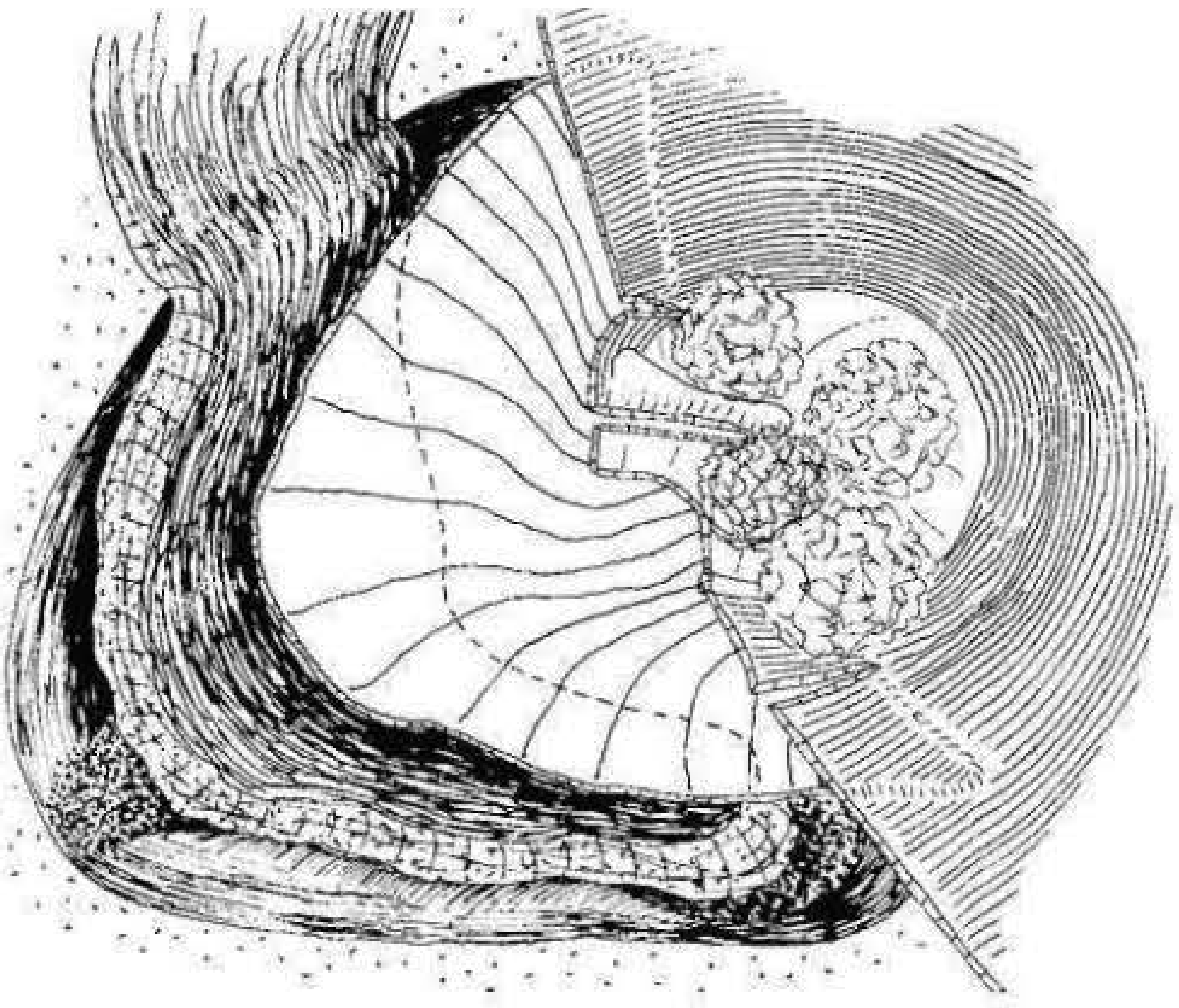


Fig. **978** The replaced ear canal skin flaps are fixed with Gelfoam balls. The lateral part of the cavity is filled with a superiorly-based bipartite subcutis–muscle flap (Figs. **881–890**)

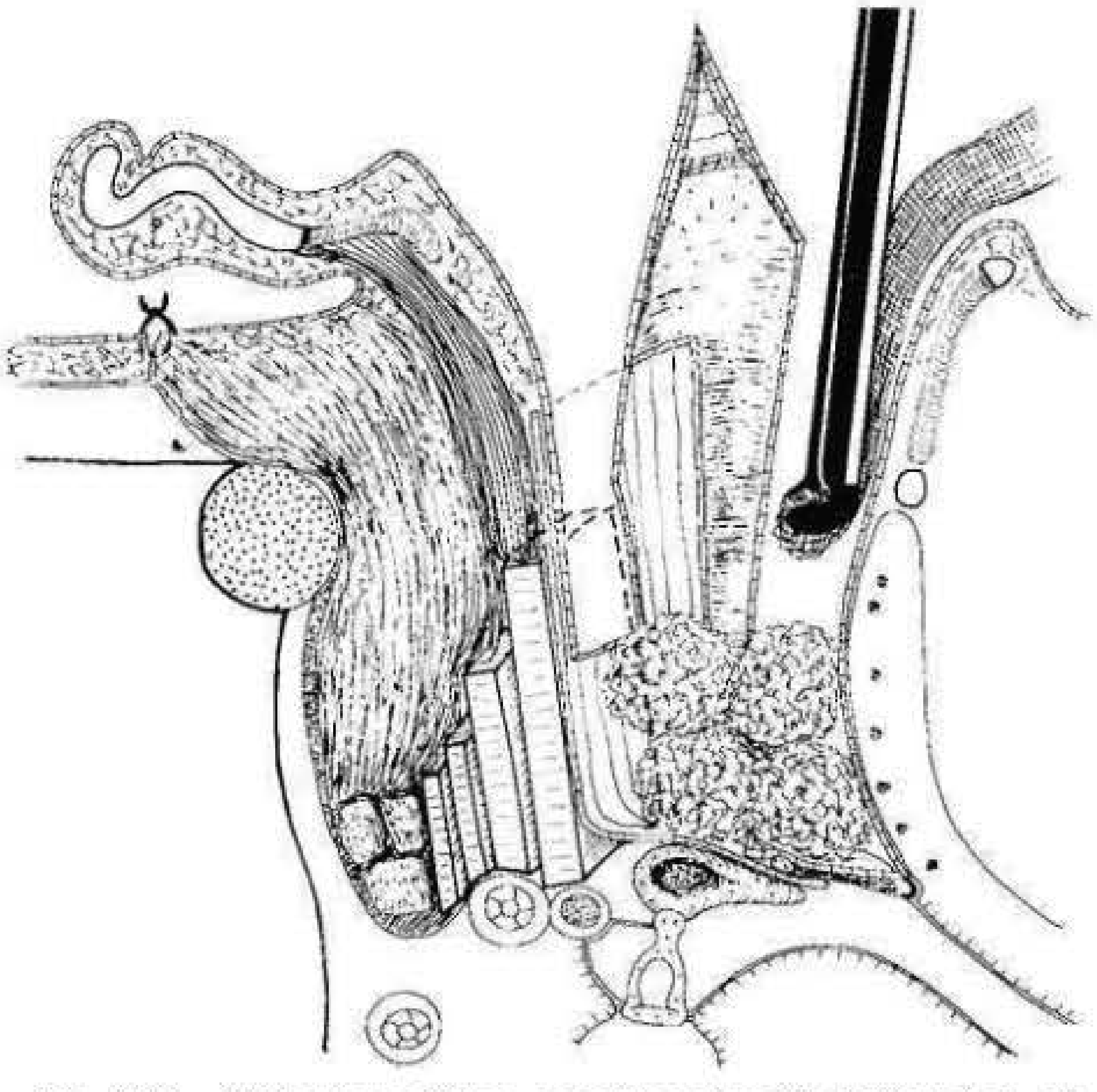


Fig. **979** Side view of the combined-graft obliteration of a large cavity with reconstruction of the ear canal wall using tragal cartilage. A large piece of cartilage is placed as medially and meatally as possible. A small Palva flap is placed laterally and meatally, and a large, superiorly-pedicled muscle flap obliterates most of the cavity. Medially, the remaining pieces of cartilage, bone, and bone paté are placed. Fascia covers ail of the reconstructed meatal wall, and ends under the posterior canal skin flap. The ear canal is widened by an incision at the 12-o'clock position, extending down to the bone and 1 cm superiorly along the helix. The ear canal is packed with Gelfoam balls and gauze moistened with oxytetracycline and hydrocortisone (Terra-Cortril) ointment

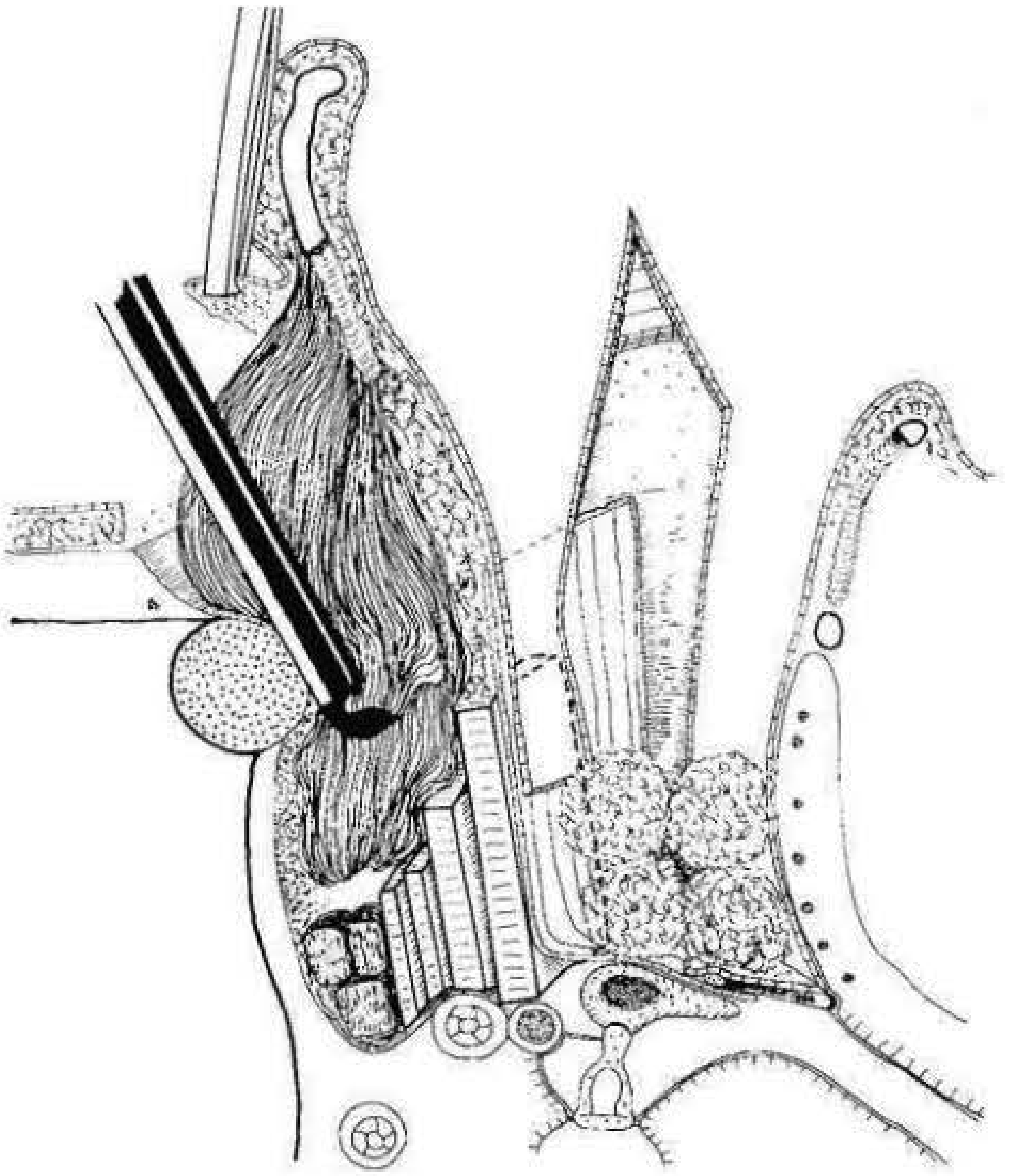


Fig. **980** Side view with some perspective of a combined-graft obliteration using a large Palva flap to obliterate the lateral part of the cavity and reconstruct the ear canal wall. After obliteration of the medial part of the cavity with tragal cartilage, bone paté, and pieces of bone, the Palva flap is brought into the proper position using a forceps. At the same time, the auricle is pulled backward into its original position. The ear canal is widened at the 12-o'ciock position brought deep into the cavity. In obliteration with a Palva flap, the following sequence is important: 1) Reconstruction of the ear canal wall with cartilage and fascia, as well as obliteration of the medial part of the cavity (Fig. **977**). 2) Placing a strip of gauze in the cavity in order to prevent accumulation of blood within it during preparation of the Palva flap and during meatoplasty. 3) Removal of the gauze just prior to placement of the Palva flap, which completes the obliteration and canal wall reconstruction (Fig. **980**).

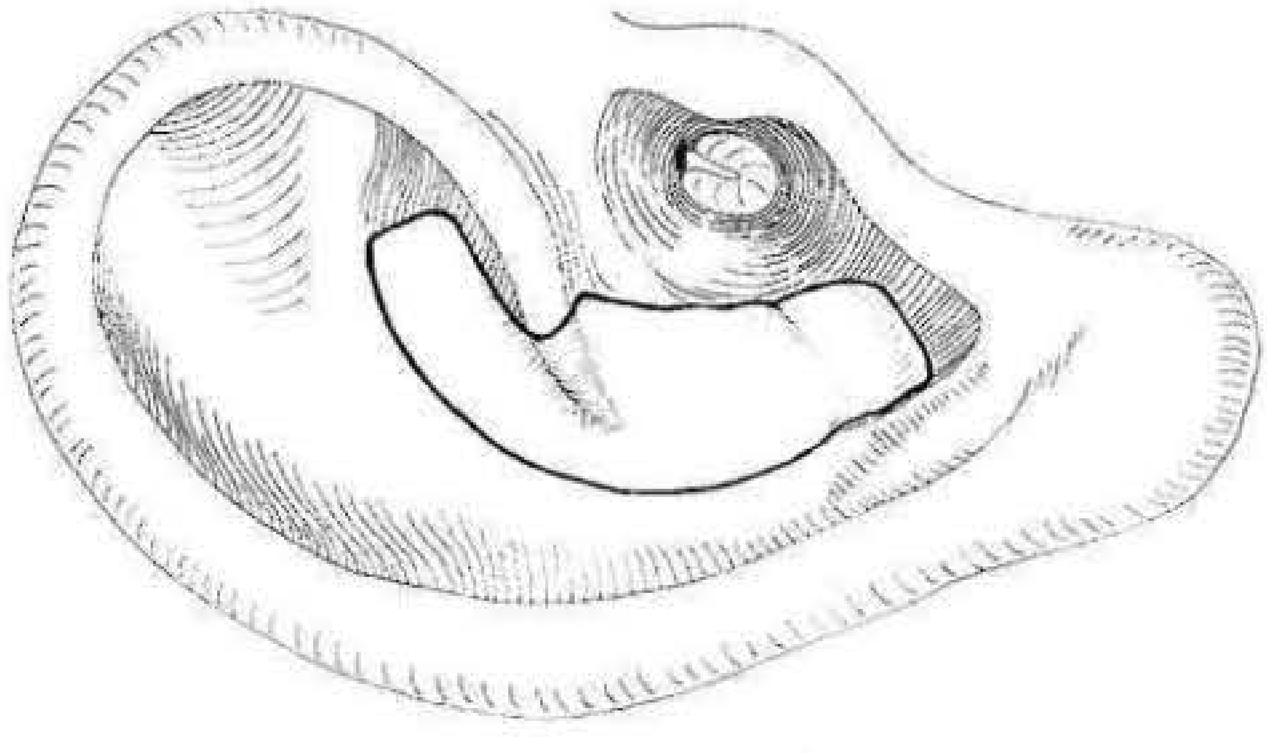


Fig. **981** The maximal extent of conchal cartilage removal in obliteration (Heermann)

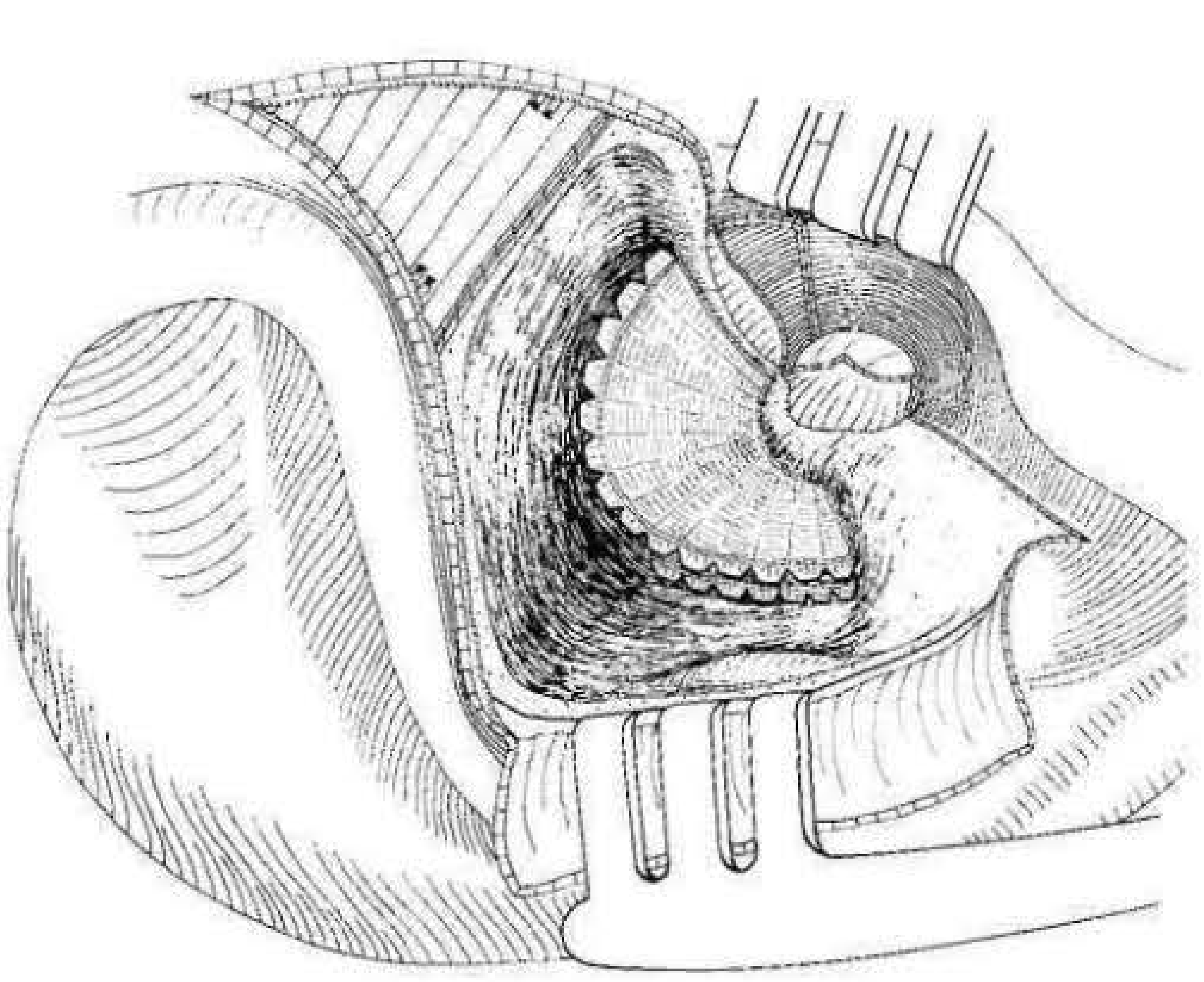


Fig. **982** **The perichondrium-palisaded cartilage mastoidplasty** (Heermann). Carpets of perichondrium–cartilage compound grafts of tragal and conchal cartilage, prepared by cutting the cartilage into palisades attached to the perichondrium, are placed in the mastoid cavity, covering the superior and posterior walls. A canal wall–down mastoidectomy is carried out with an endaural approach, using a Heermann B incision

In total obliteration using combined grafts in the retroauricular approach, the cartilage is the dominant material, but other materials are also used. The author prefers autogenous cortical bone, bone paté, and allogenous septal cartilage. These materials are placed behind the autogenous cartilage and the muscle flaps, filling the rest of the cavity. The other important materials are a large piece of temporalis muscle–fascia and, of course, the Palva flap. The meatoplasty has to be adequate; usually, a widening of the ear canal at the 12-o'clock position is sufficient, and results in a V-shaped opening of the ear canal.

Perichondrium-Palisaded Cartilage Mastoidplasty (Heermann)

Autogenous cartilage was the only obliteration material used by Heermann over many years (Heermann 1962, 1992). The canal wall–down mastoidectomy is performed with an *endaural approach* and the Heermann B incision (Fig. **659**). Tragal cartilage is removed through the intercartilaginous incision (Vol. 1, Figs. **264–266**). Conchal cartilage is removed through a separate retroauricular incision (Vol. 1, Figs. **267–280**). **A** large piece of conchal cartilage can be removed together with the anterior layer of perichondrium (Fig. **981**). This results in postoperative enlargement of the external auditory canal, which, when associated with the Heermann B incision, represents a *large meatoplasty.* The tragal and conchal cartilage are cut into palisades still attached to perichondrium, and placed on the exposed cavity walls (Fig. **982**). Heermann (1989) does not use any fascia, and claims that tragal and conchal cartilage alone, with its attached perichondrium, are the only materials required for myringoplasty and obliteration. It is evident that conchal and tragal cartilage are nowhere near large enough to provide a complete covering of the exposed walls of the cavity, and this procedure can thus hardly be called an obliteration procedure. Due to the very extensive meatoplasty resulting from conchal cartilage removal, an open cavity is the result of this technique once the canal skin flaps are replaced. Nevertheless, the cartilage covering provides a better cavity lining then epidermis alone (Fig. **983**). Insufficient obliteration using the palisade–cartilage technique is illustrated in Figure **984.** If the palisaded cartilage–perichondrium carpet is placed obliquely, extending from the posterior fossa dura wall to the lateral semicircular canal, the cavity inferior to this cartilage has to be obliterated.

The palisade technique with intact perichondrium prevents ingrowth of the epidermis through the interstices of the cartilage.

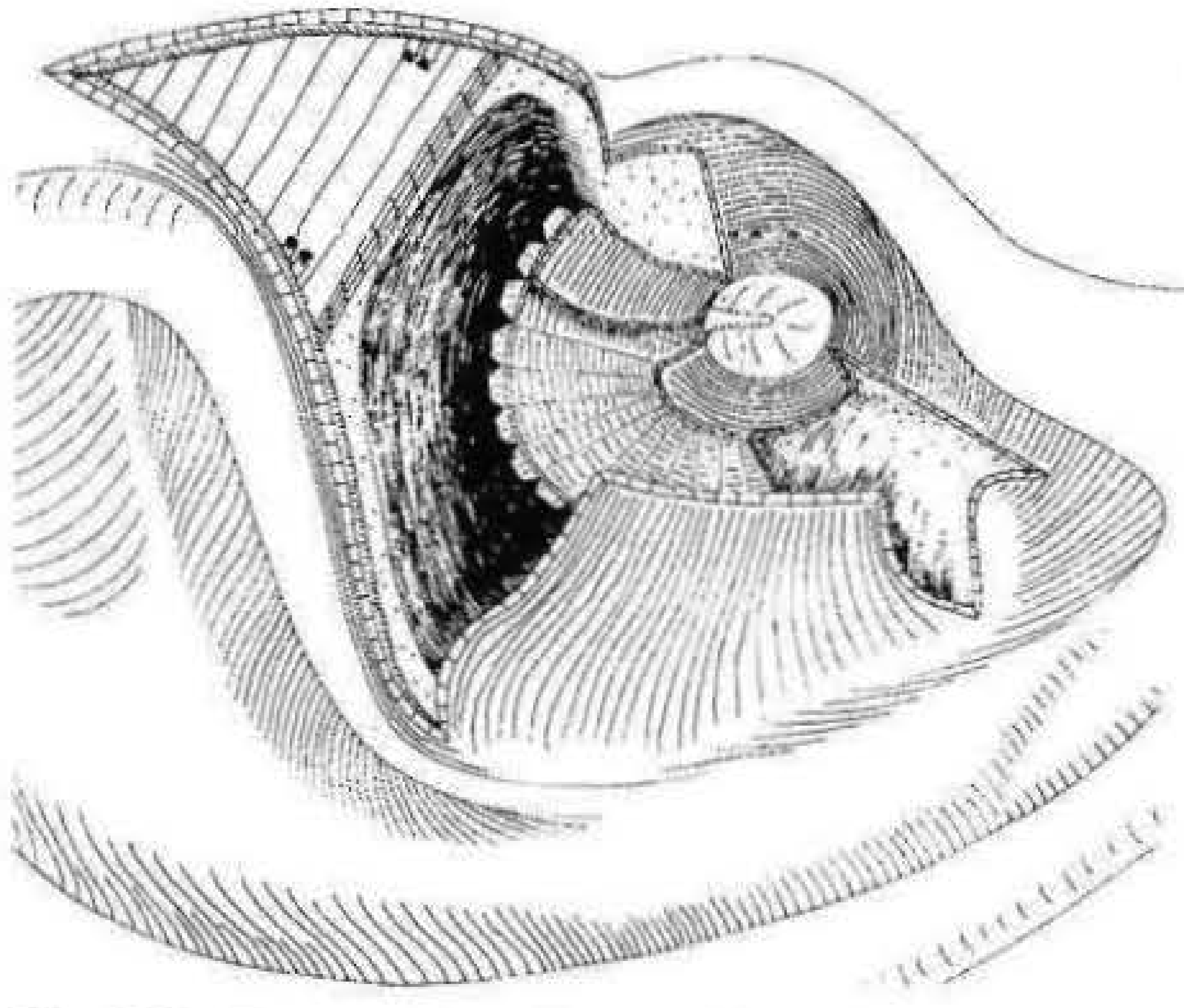


Fig. **983** The perichondrium–cartilage carpet covers the cavity walls. The Körner flap is replaced, as are the meatal skin flaps. Myringoplasty is performed using perichondrium. The ear canal is considerably enlarged

Partial Obliteration

Tragal or conchal cartilage is used in partial obliteration of particular parts of the cavity, e. g., of the supralabyrinthine space (Figs. **686, 687**), as well as in obliteration of the attic (Figs. **690–692**) (Schobel 1989, Meuser 1989) and the perilabyrinthine space. In addition, the mastoid tip can be obliterated separately using cartilage (Fig. **730**), as can a deep sinodural angle.

Besides obliteration, autogenous cartilage has also been used for reconstruction of the attic wall in canal wall–down mastoidectomy by placing cartilage plates on the preserved bony bridge and tegmen tympani or antri (Figs. **694, 696, 698**).

Allogenous Cartilage

Allogenous septal cartilage (Jansen 1963, Smyth and Dowe 1971, Strauss 1974, Preobrazensky 1977, Brask 1989), knee cartilage (Wehrs 1972, 1978), costal cartilage (Maffei and Zini 1972, Meuser 1993), as well as allogenous tragal and conchal cartilage (Heermann 1992) have all been used.

The common feature when using allogenous cartilage is that ta large amount of cartilage is usually available for obliteration. Reconstruction of the ear canal can be performed with the same allogenous cartilage material as that used for the obliteration.

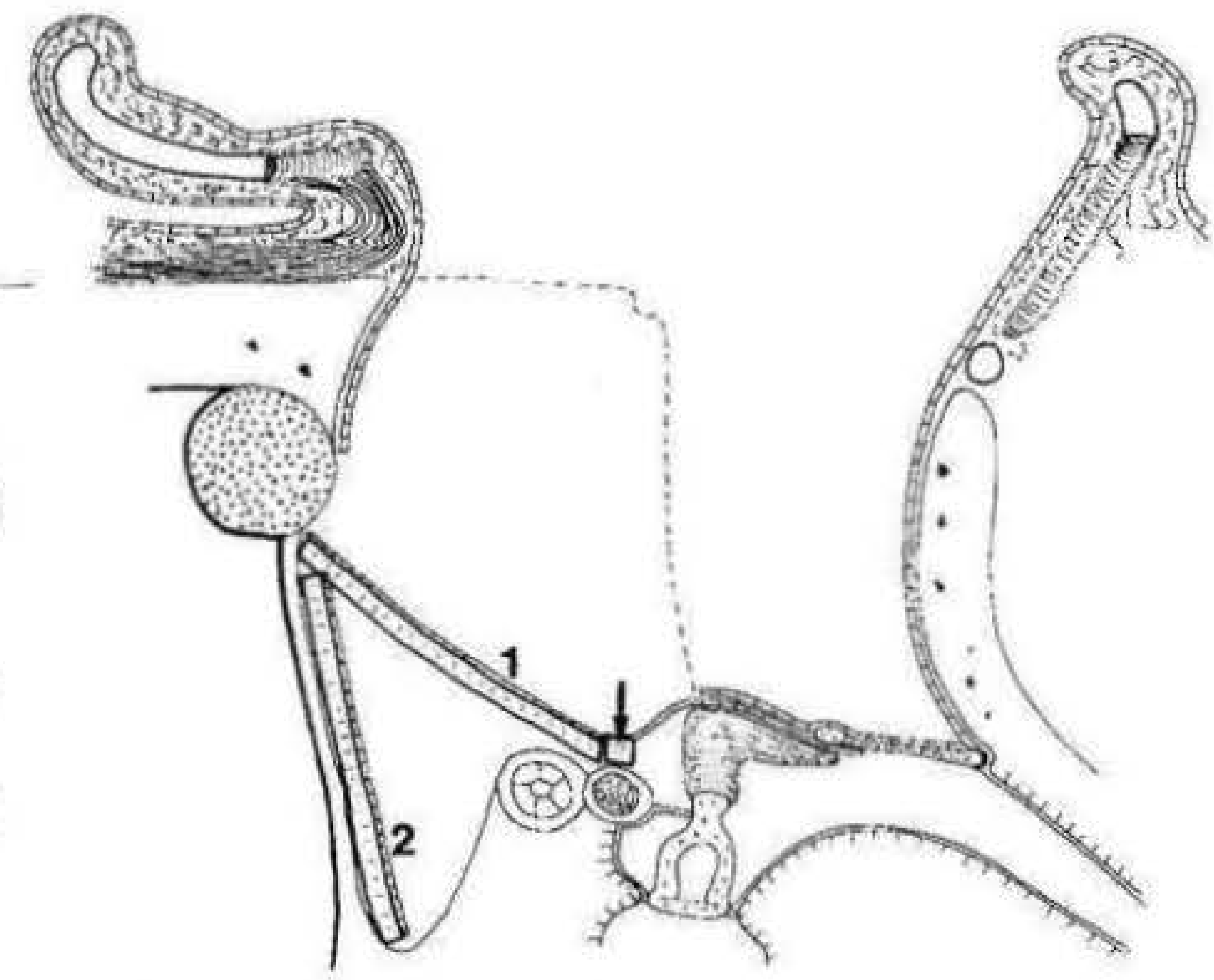


Fig. **984** Examples of various placements of the perichondrium-palisaded cartilage. If the carpet is placed between the posterior fossa dural plate and the lateral semicircular canal (1), then the medial part of the cavity has to be obliterated by other materials. If the cartilage carpet is placed along the posterior fossa dural plate (2), then most of the cavity is not obliterated at all. The ossiculoplasty is performed with an ossicle, and the ear drum is closed with perichondrium lying on a palisade of conchal cartilage (arrow). The ear canal is maximally widened, mainly because of removal of a large part of the conchal cartilage and the endaural Heermann II incision at the 12-o'clock position. The original size of the ear canal wall is indicated by a dashed line

Allogenous Septal Cartilage

The cartilage is harvested from septum operations or from cadavers, with the opportunity of harvesting large, regular plates of cartilage, which is usually stored in Cialit or formaldehyde.

Allogenous septal cartilage is used as cartilage plates (Tos 1977), as small rectangular pieces (Preobrazensky 1977), or even as crushed cartilage (Strauss 1974, Brask 1989).

Large cartilage plates. The present author has used allogenous cartilage plates in combined-graft obliteration for additional material, hidden behind the reconstructed ear canal wall after use of autogenous tragal cartilage and a Palva flap (Tos 1977, Siim and Tos 1987,1989). The method is as follows. In canal wall–down mastoidectomy or in reconstruction of old radical cavities, including the tympanic cavity, the entire tragal cartilage is placed on the medial wall of the attic, representing the reconstructed ear canal wall. It is placed as far superiorly as possible in order to tightly close the superior wall of the cavity. A piece of cortical bone is placed

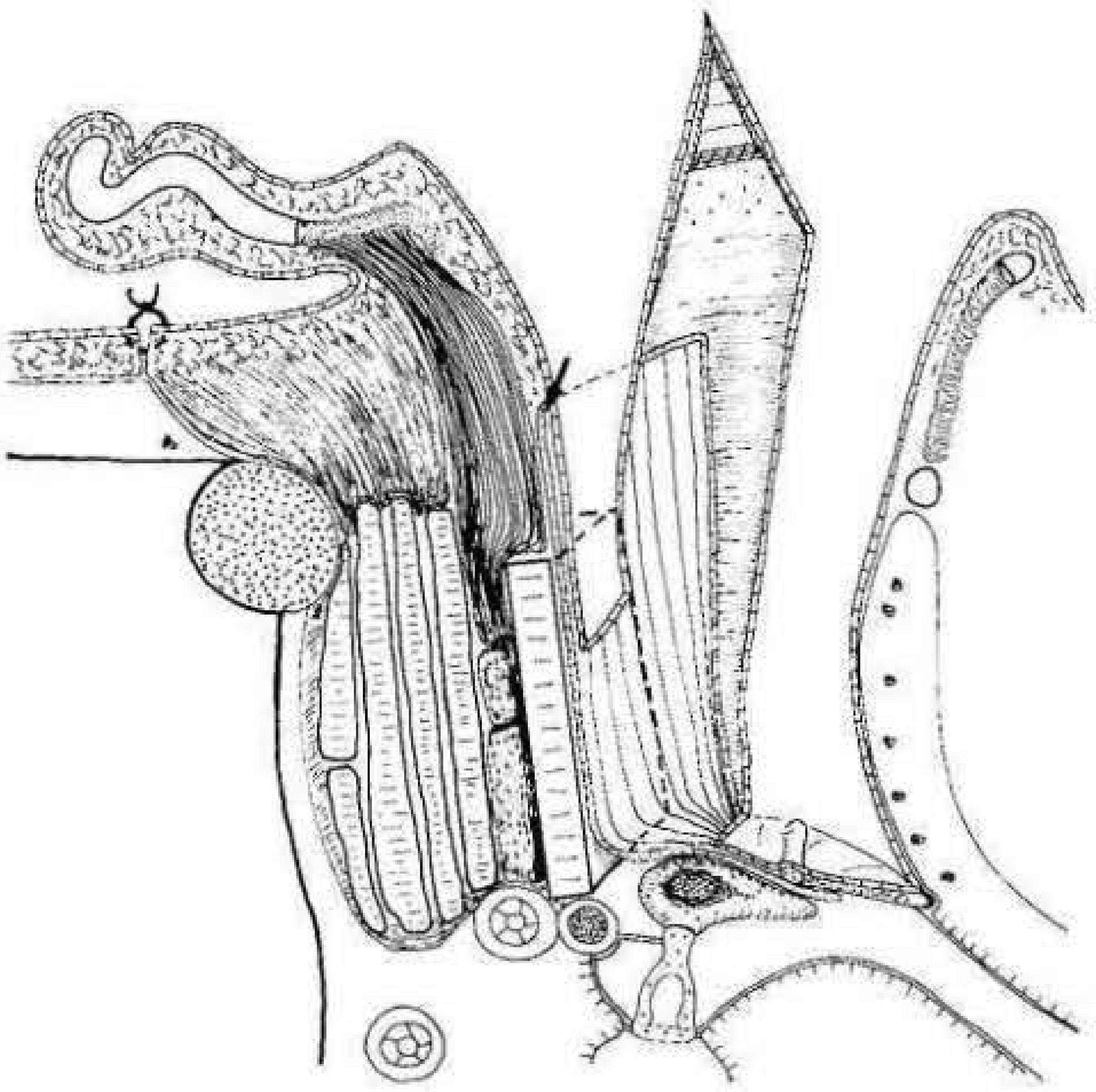


Fig. **985** **Obliteration of the cavity with large allogenous septal cartilage plates** (Tos). Behind the ear canal wall reconstructed with tragal cartilage, a Palva flap, and a piece of bone, several large pieces of allogenous septal cartilage are obliterating the posterior and medial parts of the cavity. The lateral part is further obliterated with a superiorly-pedicled muscle graft. The underlay fascia graft covers the drum perforation and the reconstructed ear canal wall; laterally, it is placed under the Körner flap (arrow). The ear canal is widened with an incision at the 12-o'clock position

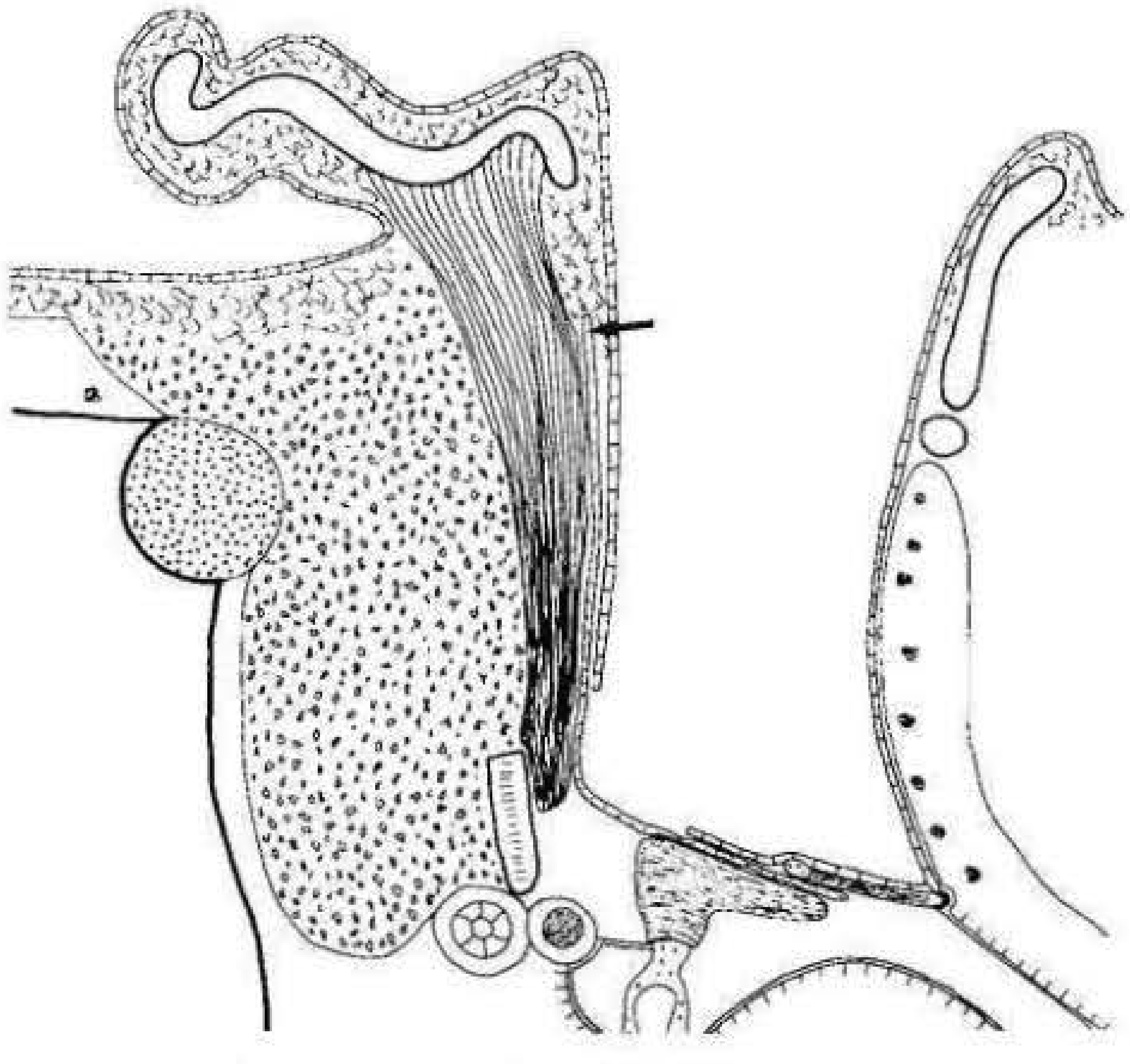


Fig. **986** **Obliteration of the cavity with crushed cartilage** (Strauss). The ear canal wall is reconstructed with a long Palva flap, and a piece of fascia ending under the posteriorly-based epithelial flap (arrow). A piece of septal cartilage is placed behind the Palva flap on the medial attic wall. The cavity is completely obliterated with crushed allogenous septal cartilage

behind the tragal cartilage to support the cartilage and partially obliterate the attic. Behind the autogenous material, several large plates of allogenous septal cartilage are placed, obliterating the rest of cavity. Myringoplasty is performed using a large piece of fascia that is turned laterally, covering the tragal cartilage and ending laterally behind a large Körner flap. Finally, a Palva flap is placed behind both the fascia and the tragal cartilage. The lateral part of the cavity is filled with a small pedicled subcutis–muscle graft, taken from the posterior or inferior region of the mastoid process. The idea behind this obliteration is to avoid contact between the allogenous cartilage and the canal skin, and in this regard at least three layers of autogenous material need to be placed anterior to the allogenous cartilage, e. g., fascia, tragal cartilage, Palva flap, and cortical bone (Fig. **985**). The ear canal is widened by an incision at the 12-o'clock position, and then packed.

After several reevaluations of 131 patients with a median follow-up of 8½ years (range 2–17½ years), 28% of the patients had no cavity, 15% had a small one, 12% a medium-sized one, and 10% had large cavities – despite the obliteration. Seventy-four percent had been permanently dry, 18% had intermittent discharge, and 8% were constantly moist. There were no differences between ears obliterated only with muscle grafts using pedicled bipartite muscle grafts (Tos 1967) and those with combined grafts.

Small cartilage plates. Preobrazensky (1977) used septal cartilage, cutting it into small pieces just before use. Histologically, he subsequently found ossified cartilage fragments along the cavity wall, but in the central part of the obliterated cavity the cartilage was partly preserved, although filled with fibrous tissue.

Crushed cartilage. Strauss (1974) used crushed septal cartilage to obliterate the cavity. First, the ear canal was reconstructed with a large piece of fascia and a large Palva flap; the crushed cartilage was then used to fill the remainder of the cavity behind the Palva flap (Fig. **986**). A small piece of septal cartilage was placed on the medial wall of the attic. It is interesting to note that Strauss used a plate of allogenous septal cartilage for reconstruction of the ear canal wall in order to ventilate the cavity, but preferred the Palva flap for reconstruction of the ear canal when obliterating the cavity with crushed cartilage.

Crushed cartilage is used in rhinoplasty for correction of saddle noses and certain other deformities. Recognizing that pieces of crushed cartilage shrink, Brask (1989) crushed it to such an extent that it looked like a cartilage paté. He constructed a special "cartilage crushing instrument" consisting of a heavy steel piston fitting into a heavy steel cavity (Fig. **987**). The end of the piston is divided into small cutting areas. Normally, two or three homogenous septal cartilages are used per obliteration. The septal cartilage is cut into small pieces and put into the steel cavity. By hammering the cartilage a few times with the piston, it becomes crushed into a paté that is then ready for use.

The obliteration technique is as follows: After ossiculoplasty, the opening between the tympanic cavity and the attic is closed using a piece of temporalis fascia, which is attached to the bony ear canal by fibrin glue. A large piece of septal cartilage, carefully shaped to the configuration of the ear canal wall, is placed behind the fascia in order to stabilize the separation between the middle ear and the attic. The attic, antrum, and mastoid cavity are filled with cartilage paté, which is mixed with fibrin glue, resulting in very rapid conversion into an elastic mass (Fig. **988**). Histologically, in patients undergoing repeat surgery for recurrent cholesteatoma, the crushed cartilage was surrounded by rich, vascularized connective tissue. Several advantages have been noted: 1) The cartilage is not destroyed by cholesteatoma, as bone is. 2) It does not shrink. 3) It prevents reinvasion of cholesteatoma into the mastoid cavity. 4) It is very suitable for covering a labyrinthine fistula. In a few cases, however, the cartilage paté was removed due to discharge.

Allogenous Knee Cartilage

Using knee cartilage for reconstruction of the ear canal wall, Wehrs (1972), in some cases with poor tubal function, also obliterated the cavity using knee cartilage. The cartilage is cut into small pieces and placed in the cavity behind the reconstructed ear canal wall. Wehrs, however, prefers ventilation of the cavity (Fig. **834**).

Allogenous Costal Cartilage

Costal cartilage is firmer and stiffer than conchal and tragal cartilage. As autogenous material, it is widely used in rhinoplasty, but apparently there is no literature dealing with obliteration using autogenous rib cartilage. Zini (1994) consistently uses slices of allogenous costal cartilage placed behind the reconstructed ear canal wall (Maffei and Zini 1972).

Filipo and Barbara (1986, 1988) used a combination of rib cartilage plates, bone paté, and fibrin glue, filling out the cavity in a specific way (Fig. **989**): The cartilage plates are arranged in several rows, filling the entire cavity. The bone paté and fibrin glue fill the interstices between the cartilage plates. The advantage of costal cartilage is that the slices can be adapted exactly to the unique anatomical situation. When filling a large cavity, it may be a problem to harvest enough autogenous material. The advantage of the rib technique is its great adaptability to the pathology and the size of the cavity to be obliterated.

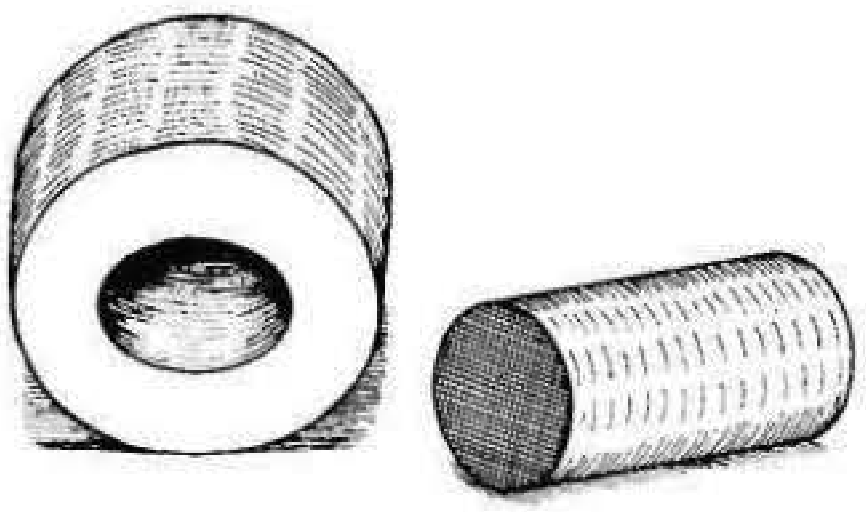


Fig. **987** The cartilage-crushing instrument, consisting of a steel piston with the end divided into small cutting areas, and a steel cavity

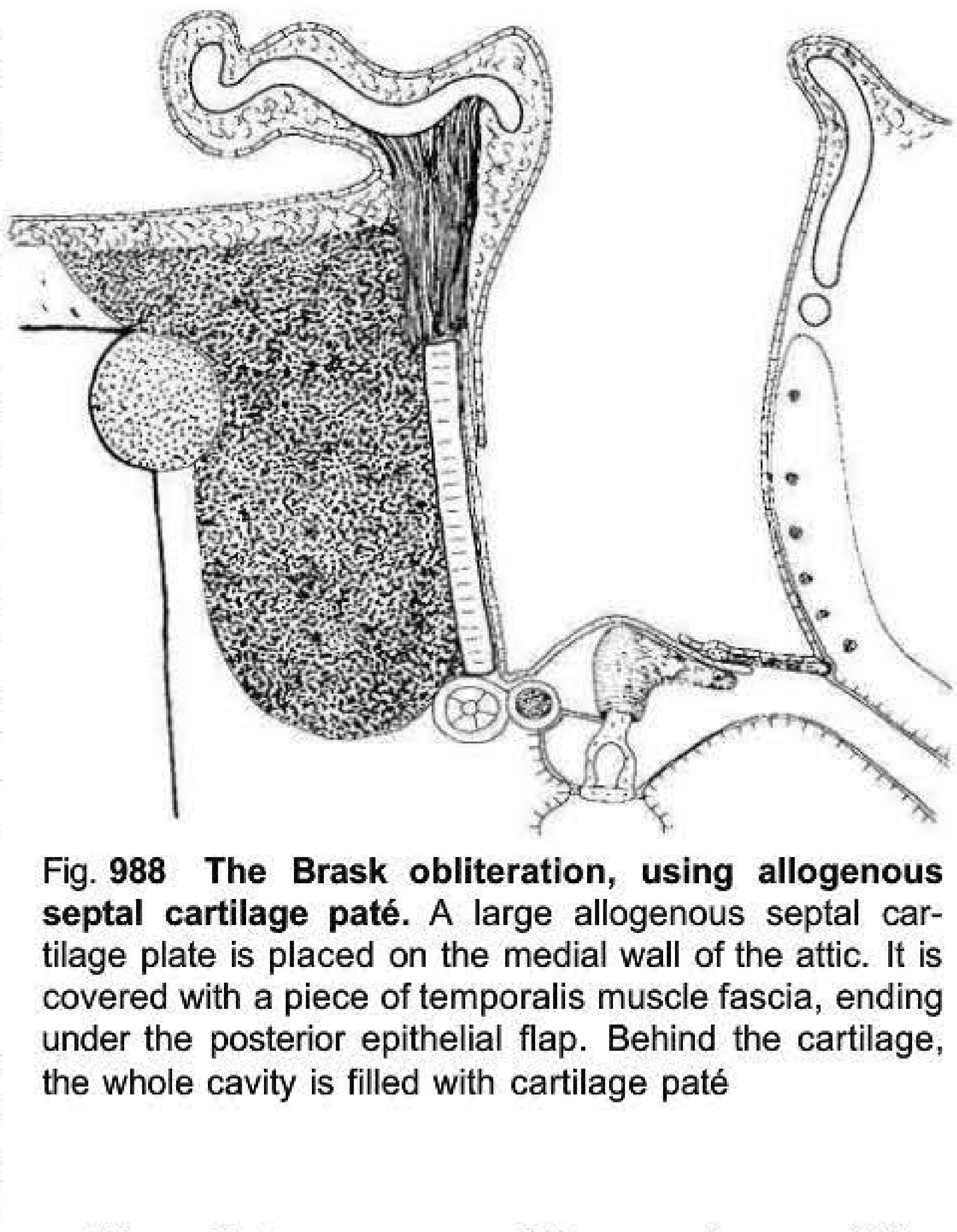


Fig. **988** **The Brask obliteration, using allogenous septal cartilage paté.** A large allogenous septal cartilage plate is placed on the medial wall of the attic. It is covered with a piece of temporalis muscle fascia, ending under the posterior epithelial flap. Behind the cartilage, the whole cavity is filled with cartilage paté

Meuser (1993) uses rectangular pieces of rib cartilage in obliteration of canal wall–down mastoidectomy cavities and in old radical cavities. With an endaural approach, Meuser first reconstructs the ear canal wall with autogenous tragal cartilage, and then fills the cavity with many small pieces of allogenous costal cartilage (Fig. **990**).

It is the present author's strong belief that cartilage is a good obliteration material that leads to very few complications. Even if it shrinks and become fibrotic, with the creation of cavities, the lining of such a cavity is firm, with good migration properties. In particular, the walls of the cavity are smooth, without obstacles, and easy to clean. However, widening of the ear canal is recommended in combination with obliteration.

However, because of risk of AIDS, allogenous cartilage cannot be used in many countries, requiring it to be sterilized before use. It has to be replaced by autogenous materials, cartilage, muscle, bone, or fatty tissue.

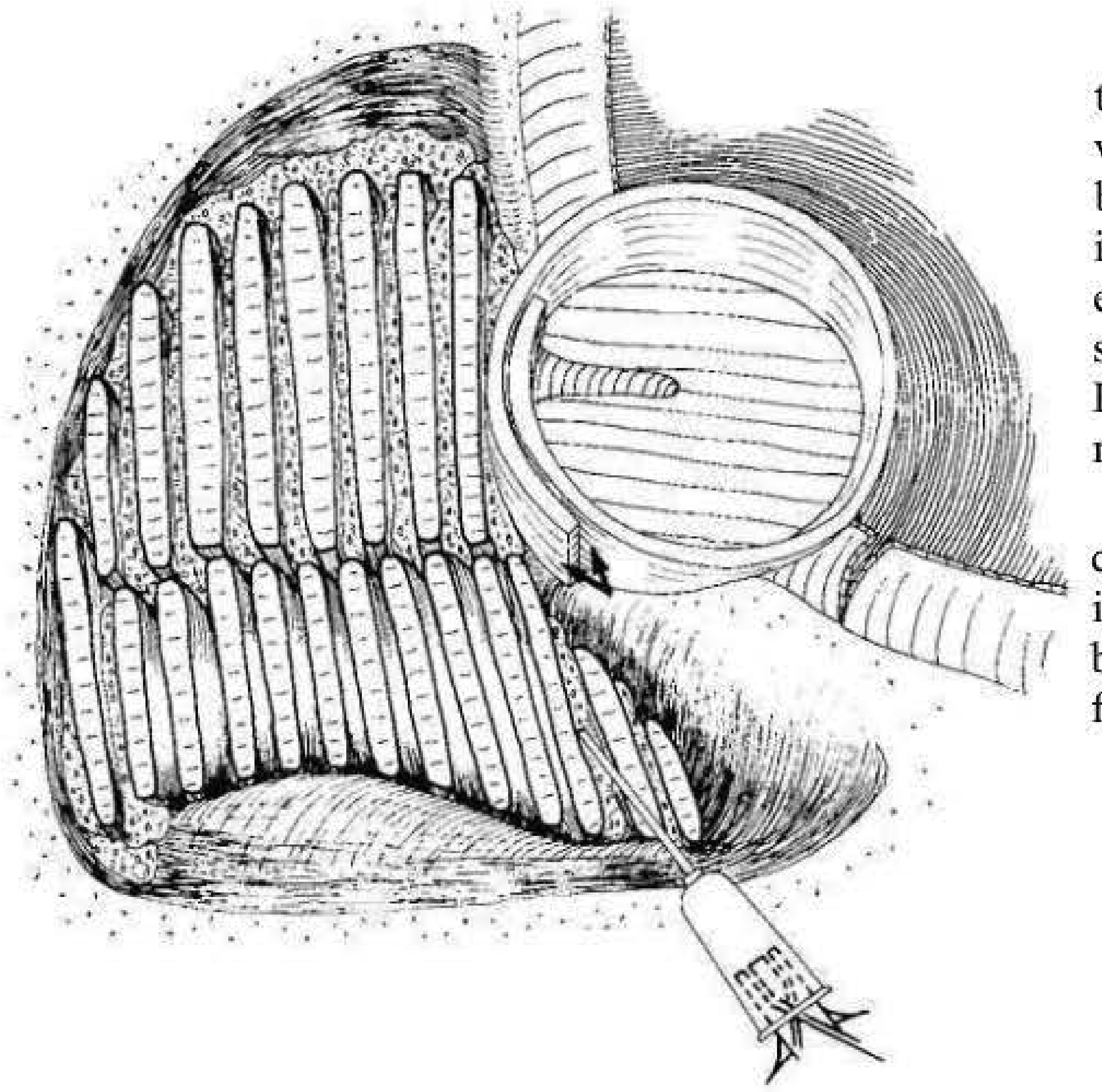


Fig. **989** **Obliteration of the cavity using allogenous rib cartilage slices** (Filipo and Barbara). After positioning a roll of Silastic (arrows) to delimit the middle ear region from the cavity, slices of costal cartilage are placed in several rows to fill out the entire cavity. Bone paté and fibrin glue fill out the interstices between the slices

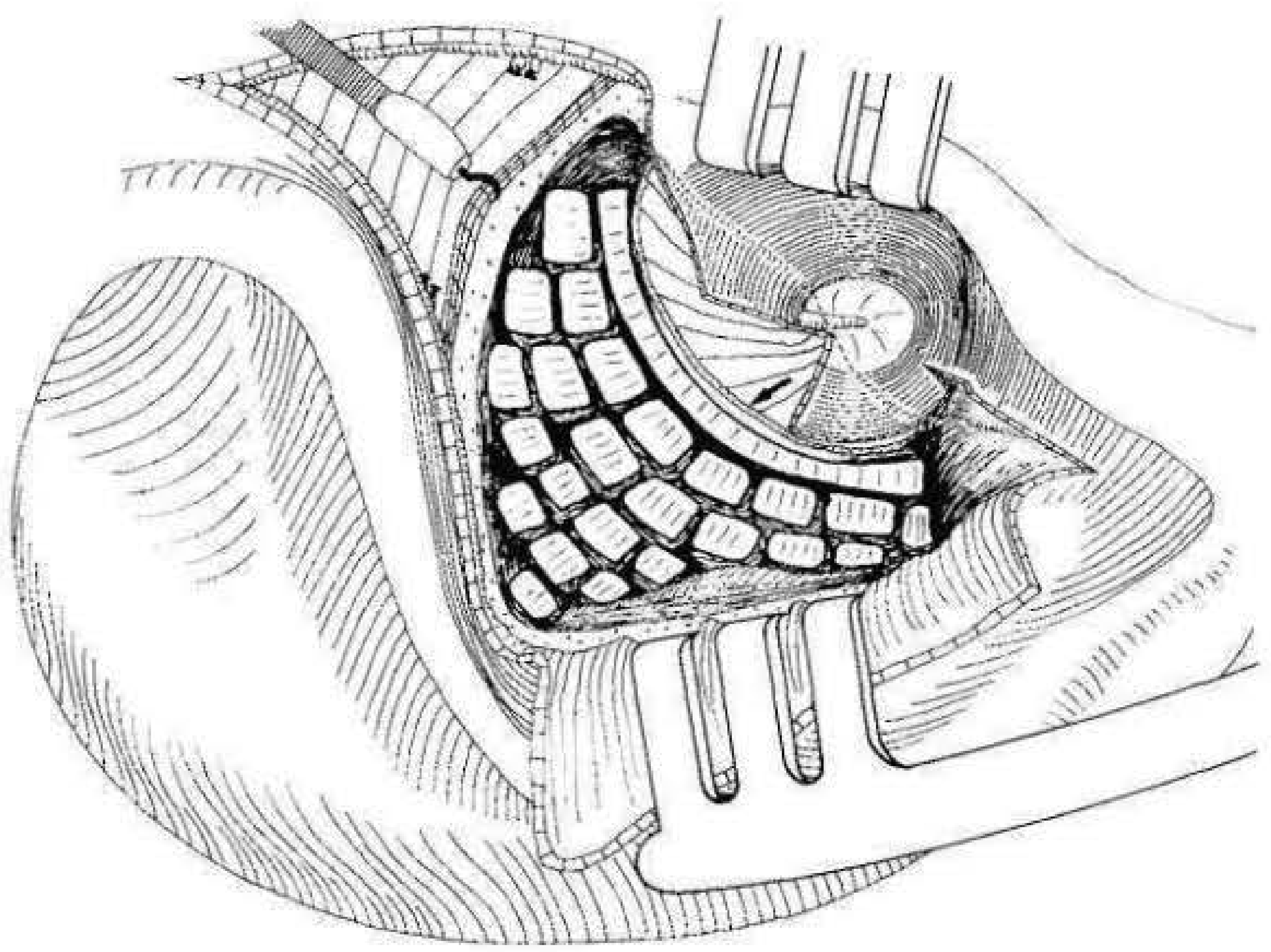


Fig. **990** **Obliteration of an endaural canal wall–down mastoidectomy cavity with pieces of costal cartilage** (Meuser). The ear canal wall is reconstructed using autogenous tragal cartilage. The perforation is closed with a piece of fascia extending over the cartilage (arrow), and meatal skin flaps cover the cartilage and the fascia. Behind the cartilage, many rectangular pieces of costal cartilage completely obliterate the cavity

20 Cavity Obliteration with Bone

Obliteration of the mastoid cavity has been in use since the early 1960s (Guilford 1960, Schiller and Singer 1960, Schiller 1961). The bone used in obliteration varies in its origin and shape, and it is applied either alone or in combination with various other materials. In obliteration or ear canal wall reconstruction, autogenous cortical bone from the mastoid process is usually used (Guilford 1960, Portmann 1966, Ekvall 1973, 1980, 1987, Pou 1977, Palva 1989, Magnan et al. 1991, Shinkawa and Sakai 1990). Besides orthotopic bone from the temporal bone, heterotopic cancellous bone from the iliac crest (Schiller and Singer 1960, Schiller 1961, 1963) and from the the tibia (Filipo and Barbara 1986) has been used.

Heterotopic Cancellous Bone

Autogenous cancellous bone is widely used in orthopedic surgery to fill bony defects after surgery on cysts and benign tumors of long bones. It is easily adapted and integrated into the bony defect, providing for good healing. It should be the ideal material for obliteration of the mastoid cavity, where no stress forces are involved and the site is normally occupied by cancellous bone. Since there is often insufficient cancellous bone in a poorly pneumatized or sclerotic mastoid process with cholesteatoma, heterotopic cancellous bone could be used, but the harvesting of heterotopic bone creates significantly more morbidity than harvesting orthotopic bone.

Iliac Crest Cancellous Bone

This method was the very first well-described obliteration method. The bone is harvested through an 8-cm incision extending posteriorly and slightly laterally from the anterosuperior iliac spine. The iliac crest is denuded of periosteum for 6–7 cm, and within this segment, one horizontal cut and two vertical cuts (1–2 cm long) are made with an osteotome through the *outer* layer of the cancellous bone, and a "lid" of the iliac crest is swung away medially (Fig. **991a**). Two further vertical cuts are then made with an osteotome within this segment, through the outer cortical layer only, and the flap of cortical bone, which is attached below, is pushed laterally, exposing the middle cancellous layer (Fig. **991b**). From this layer, several strips of cancellous bone 2.0×0.2 cm are removed with a sharp osteotome, and shaped as required for the cavity (Fig. **992**). The lid and the lateral cortical flap are replaced, and the wound is carefully closed in layers after all bleeding has stopped (Fig. **993**).

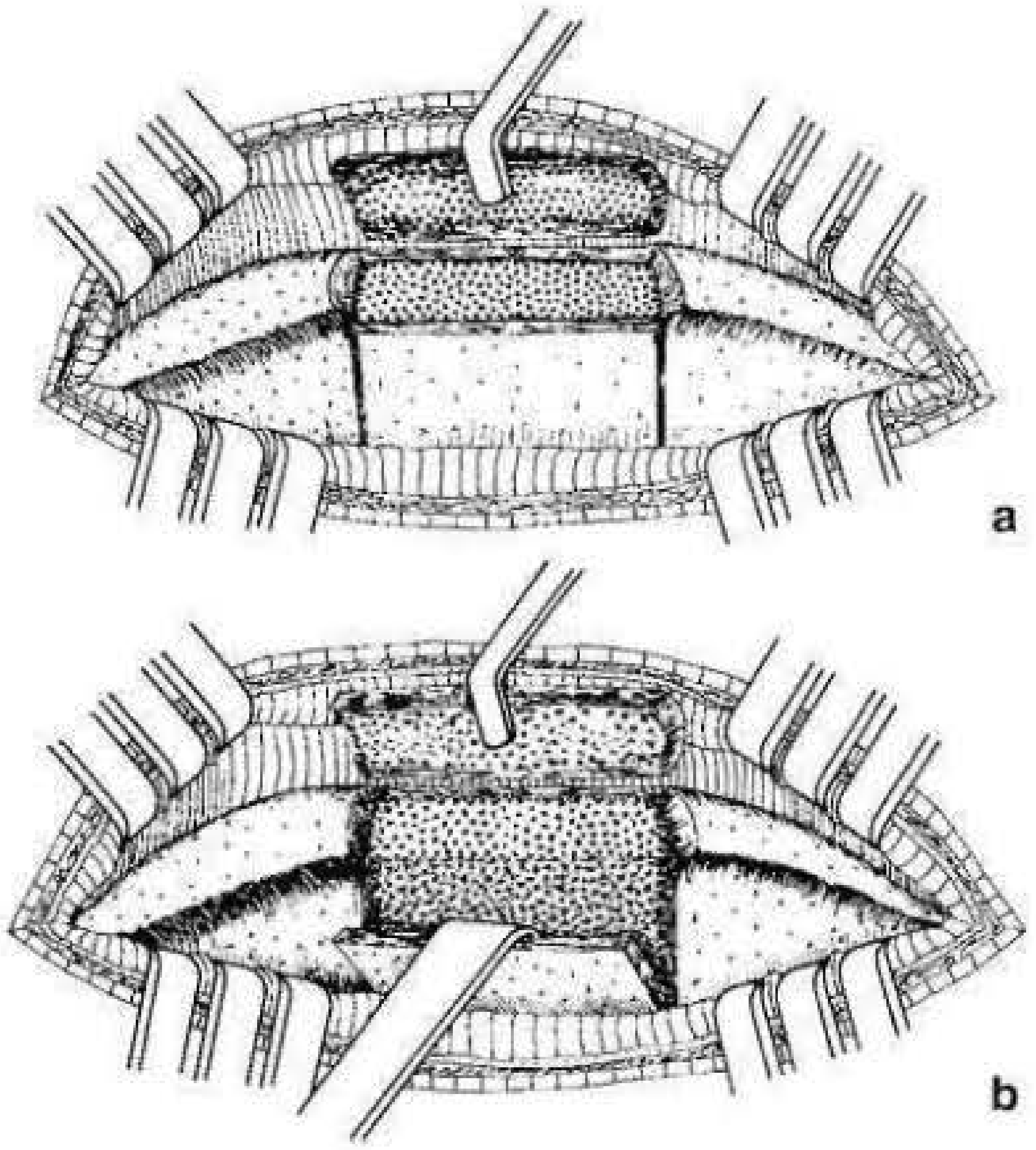


Fig. **991** **Harvesting strips of cancellous bone from the iliac crest** (Schiller): **a** After incision along the iliac crest, a lid of the iliac crest is chiseled and lifted. Cancellous bone is visible. Using a chisel, two vertical cuts are made along the outer cortical layer. **b** Cortical bone from the posterior side of the iliac crest is chiseled and pulled down, exposing the cancellous bone layer

The harvested cancellous pieces of bone are stored in a solution containing antibiotics during the operation. After a canal wall–down mastoidectomy with preservation of as much of the ear canal skin as possible and creation of superior and inferior ear canal skin flaps, the strips of iliac bone are trimmed and adapted to the size of the cavity (Fig. **994**). The strips of cancellous bone are placed either vertically or horizontally in the depths of the cavity. The first level of strips is placed over the lateral semicircular canal, behind the facial ridge. The second level of strips is arranged in a similar way (Fig. **995**), and placed first meatally, creating a bony ear canal wall, and then in the remaining cavity. Further obliteration is carried out using either horizontal or vertical bone strips (Fig. **996**). The tympanomeatal skin flaps are placed on the attic wall superiorly and inferiorly, to encourage further epithelialization of the posterior ear canal wall. A modified Körner flap hangs down in a curtain-like manner to cover the lateral part of the posterior bony ear canal wall. Inserting too many strips of bone should be avoided, since it may result in narrowing of the external auditory canal.

Initially, covering the bone with fascia was not generally performed. Currently, this technique can be performed by placing fascia as an underlay graft covering the meatal part of the new ear canal, or even using tragal cartilage. For lateral covering, a Palva flap can be used (Fig. **997**). Larger interstices between the bone strips can be filled with autogenous bone paté.

This obliteration method was used by Schiller in the fenestration operation, and in such cases, of course, the bony strips have to be placed posterior to the fenestrated lateral semicircular canal. In 32 cases observed for a period of 8–12 months postoperatively, 22 proved completely successful with total obliteration of the cavity. In one case, the skin covering was incomplete. It was shown that the cancellous bone graft had been replaced by new bone, i. e., it had integrated with the mastoid bone. Schiller described the following advantages of his technique: 1) complete obliteration, 2) restoration of the contour of the mastoid bone and the external auditory canal, and 3) reduction of postoperative treatment to a minimum.

The only fair criticism of Schiller's technique is the need to harvest bone from the iliac crest, resulting in pain and morbidity. The fact that the patient needs to remain in bed for 14 days is probably the reason why this procedure has never become popular worldwide.

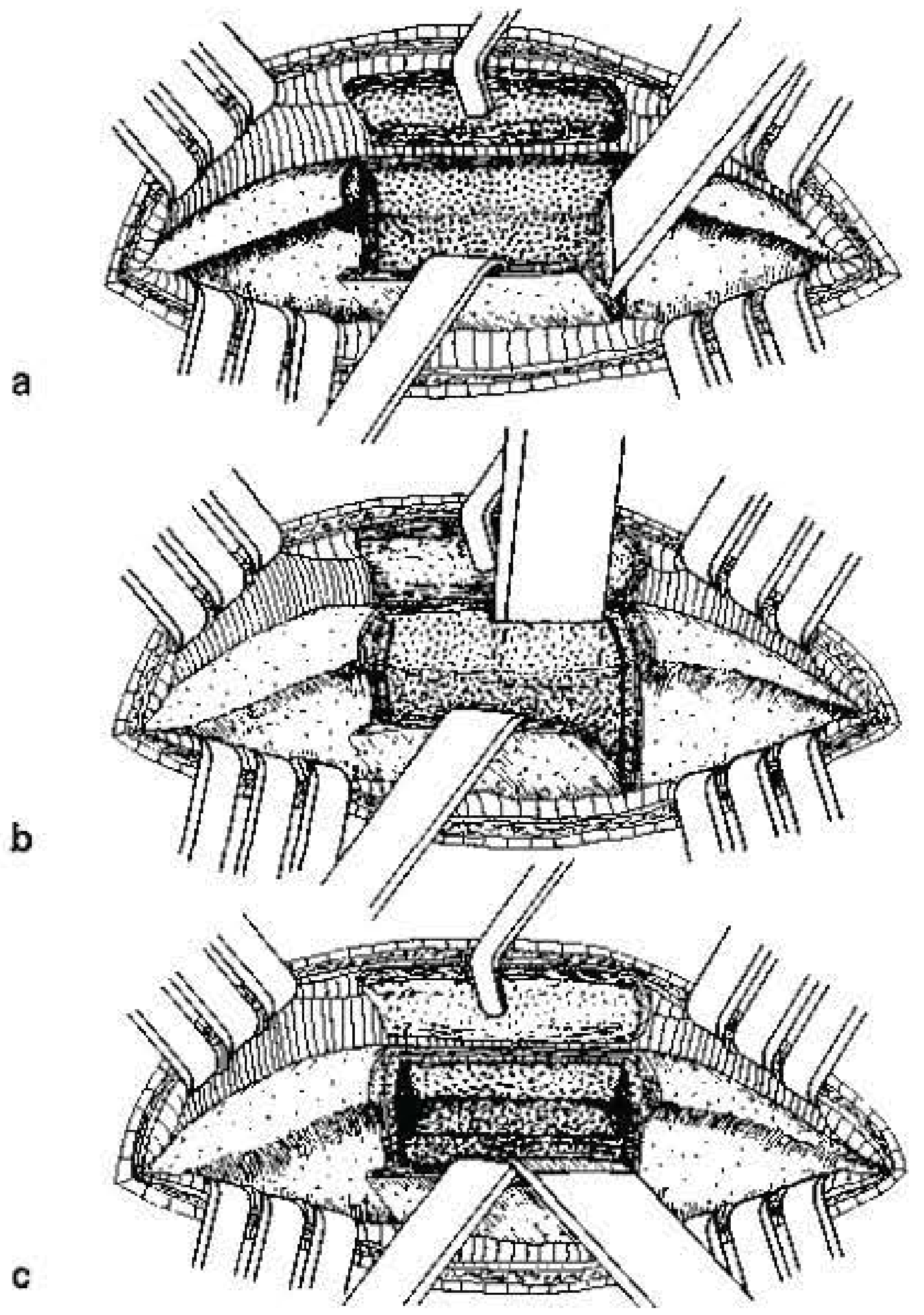


Fig. **992a, b** Removal of the strips of cancellous bone using a sharp, flat chisel. **c** Several strips of bone are removed

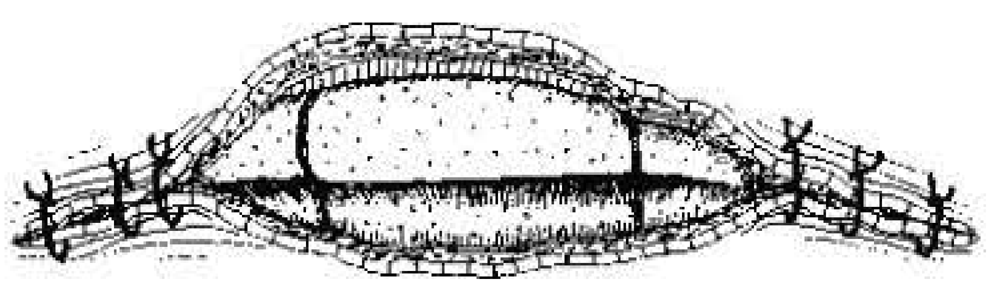


Fig. **993** The lid is replaced, and the incision is sutured

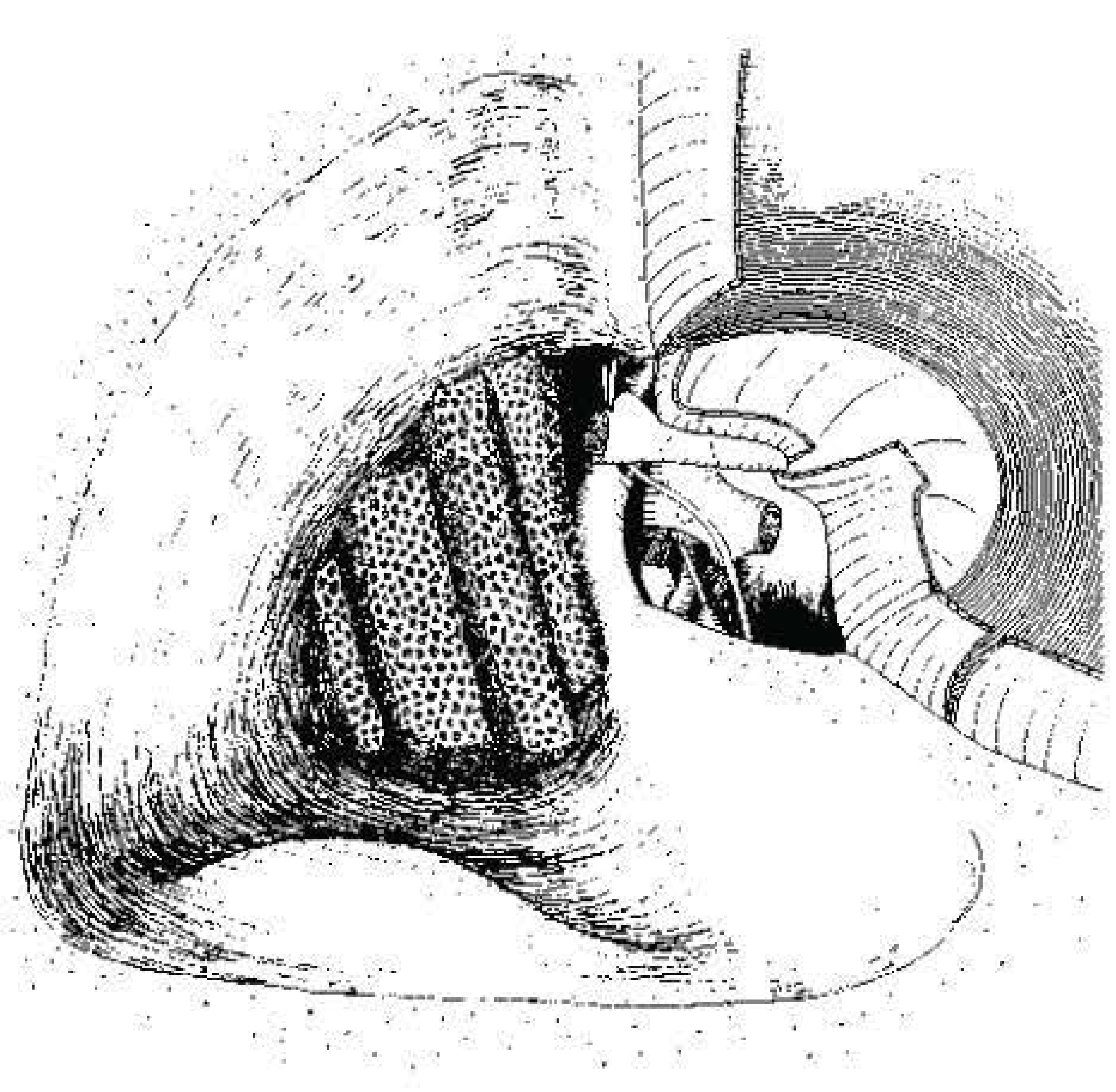


Fig. **994** **Mastoid osteoplasty with iliac crest cancellous bone** (Schiller). After canal wall–down mastoidectomy, four strips of cancellous bone of various sizes are placed vertically on the medial wall of the cavity

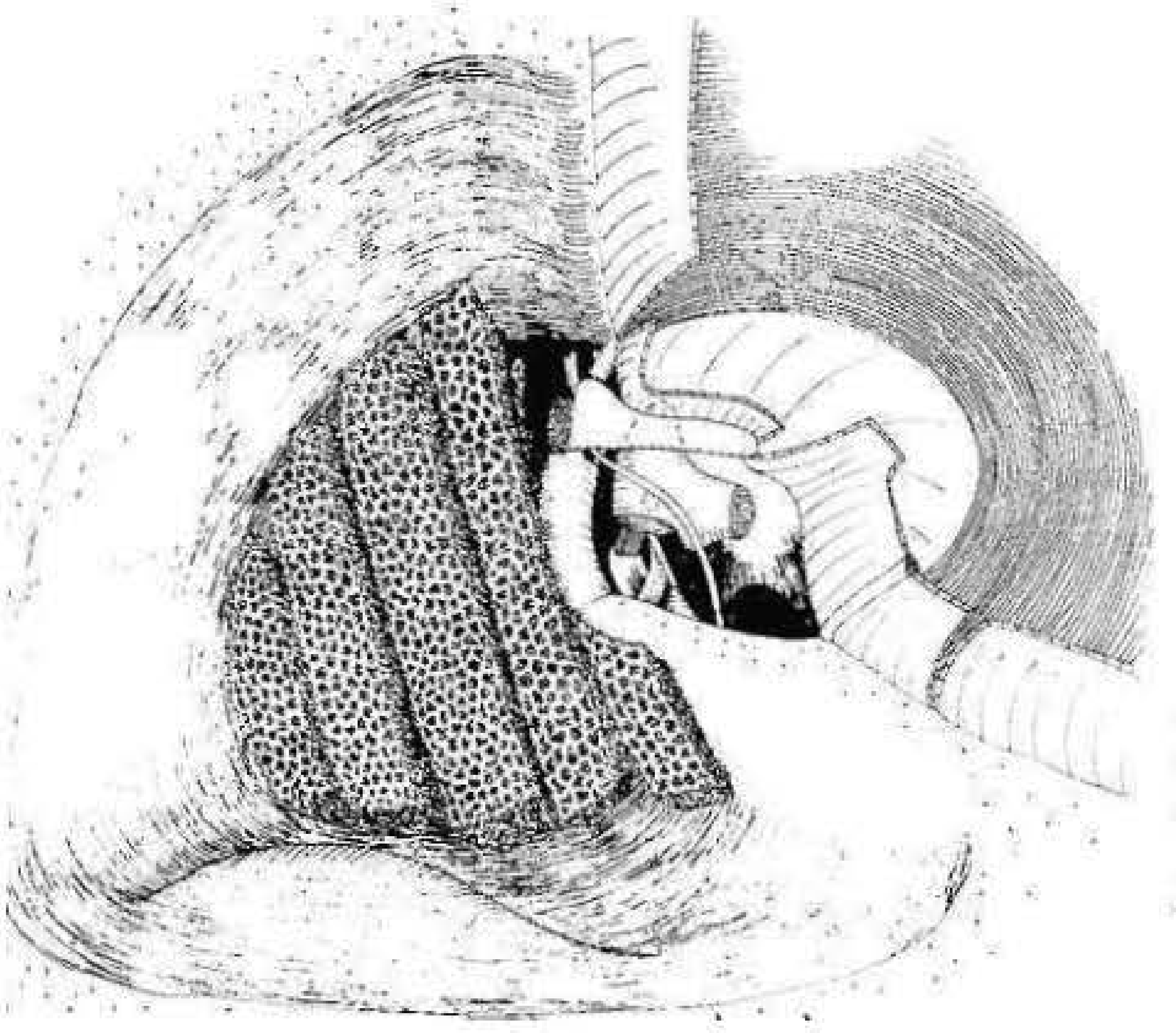


Fig. **995** The second layer of cancellous bone strips is placed vertically on the first layer

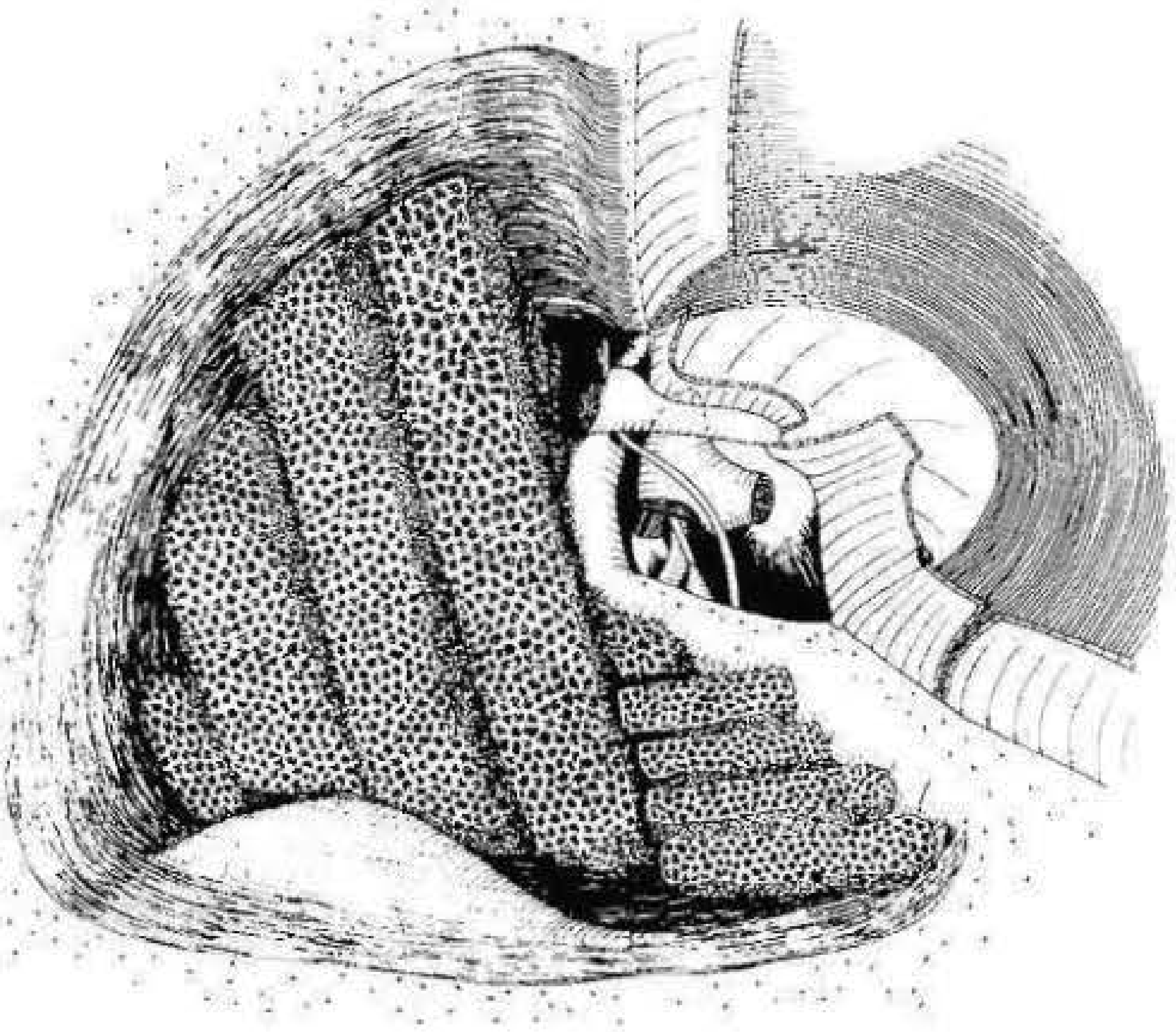
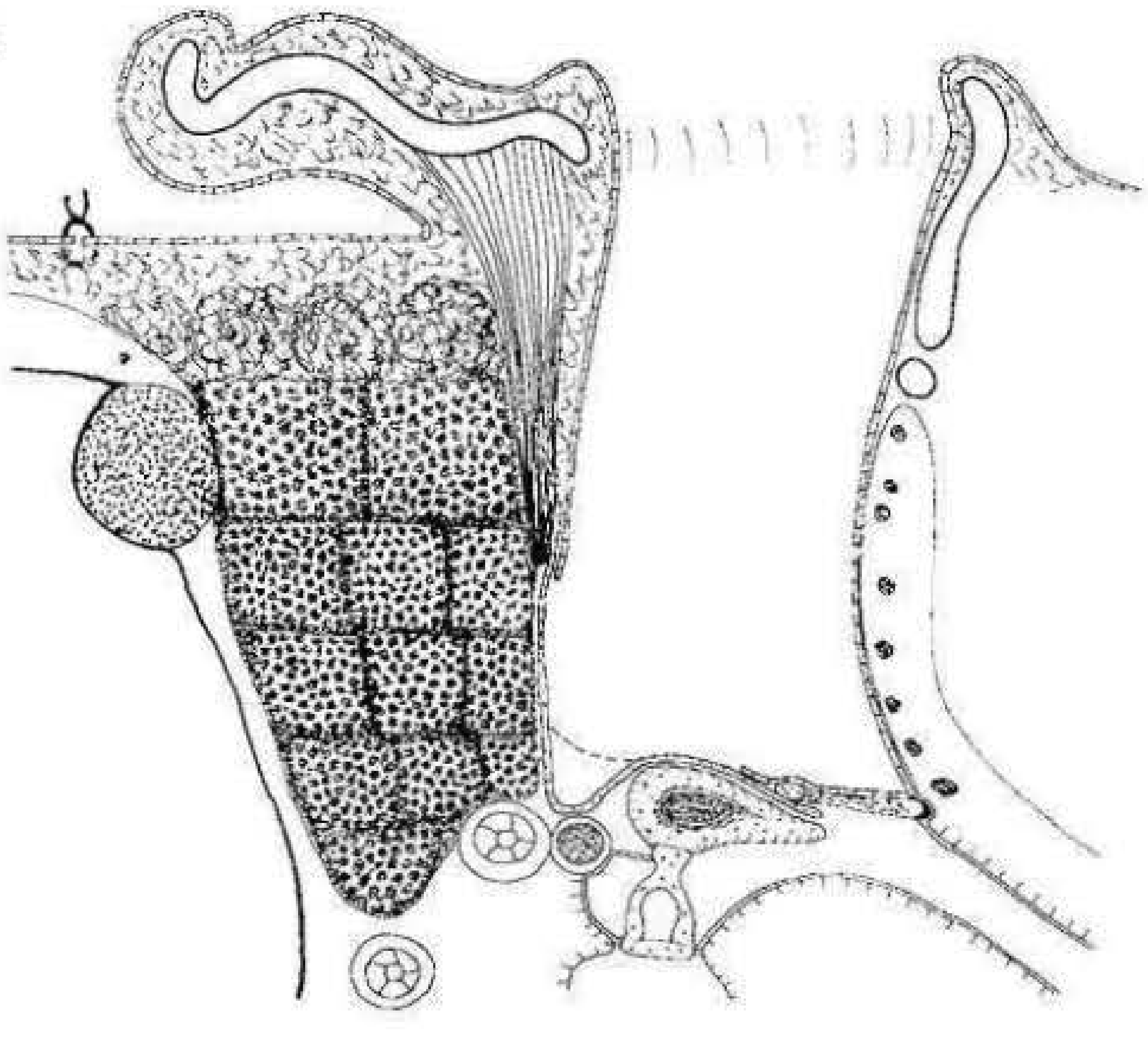


Fig. **996** The third and the fourth layers of bone are placed in the lateral part of the cavity. Some strips are placed in a vertical direction, some in a horizontal one

Fig. **997** Side view of the obliteration with iliac crest cancellous bone, showing the position of the bony strips. The fascia covers the meatal side of the strips, and laterally Gelfoam, a subcutis–muscle flap, and the periosteum cover the bone. The ear canal is somewhat widened. The fascia goes down onto the facial eminence, but it could also run directly onto the bone (dashed), leaving more of the attic ventilated. The incus is interposed



Tibial Crest Cancellous Bone

Filipo and Barbara (1986, 1988) have used autogenous cancellous bone taken from the tibial crest using a trocar (Fig. **998**). After reconstruction of the tympanic cavity and packing of the ear canal, the tympanic cavity is separated from the mastoid cavity by a large roll of Silastic. Spongioform bone from the tibia mixed with fibrin glue is placed behind the roll. The spongy bone is covered with fascia, and the epithelial flaps from the radical cavity are replaced.

Additional reconstruction of the ear canal with autogenous cartilage and a Palva flap is needed in this method in order to separate the bone chips from the canal skin.

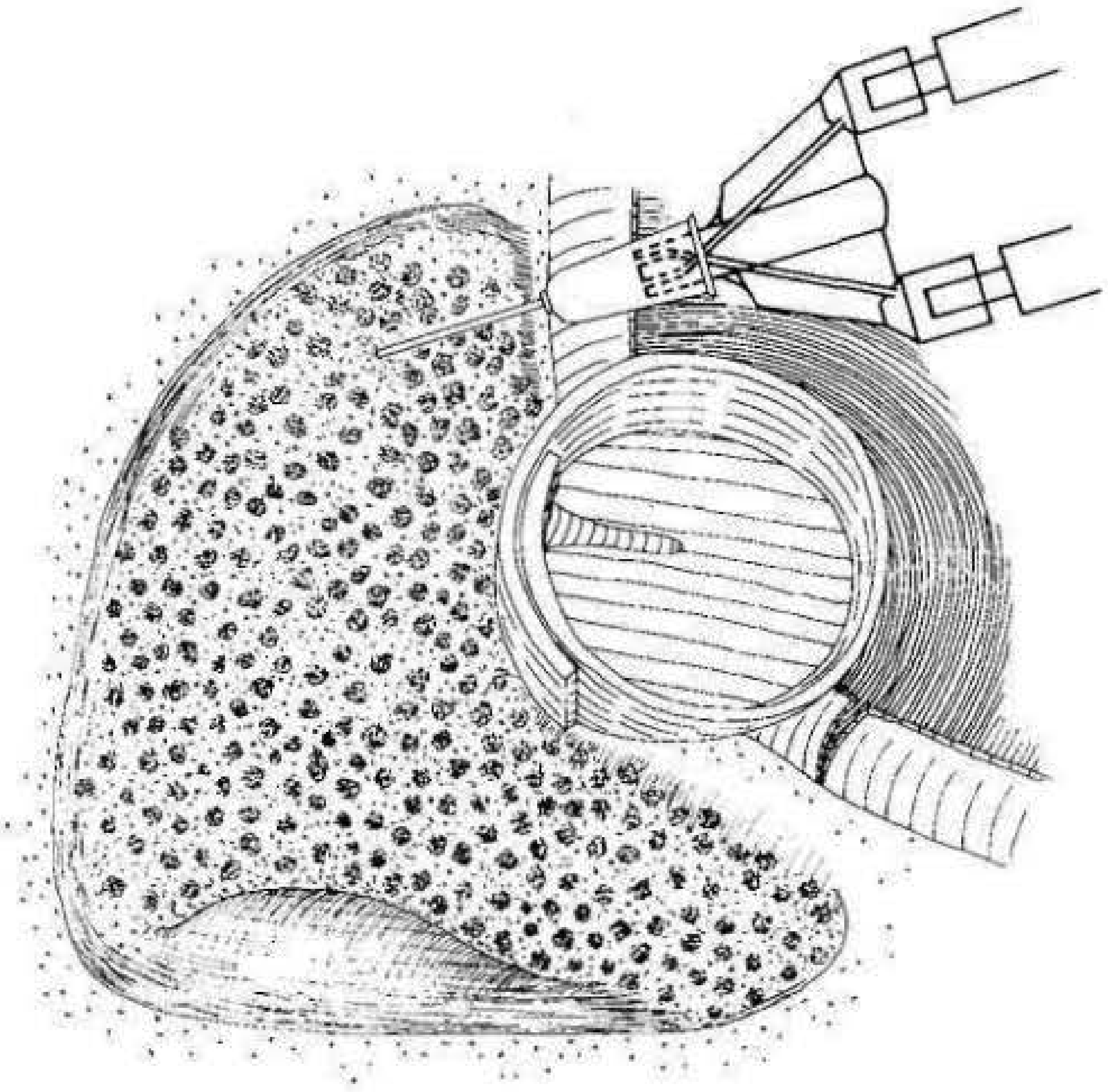


Fig. **998** **Obliteration with autogenous cancellous bone chips from the tibial crest** (Fillipo and Barbara). The tympanic cavity is separated from the mastoid cavity with a roll of Silastic. The mastoid cavity is filled with cancellous bone chips and fibrin glue

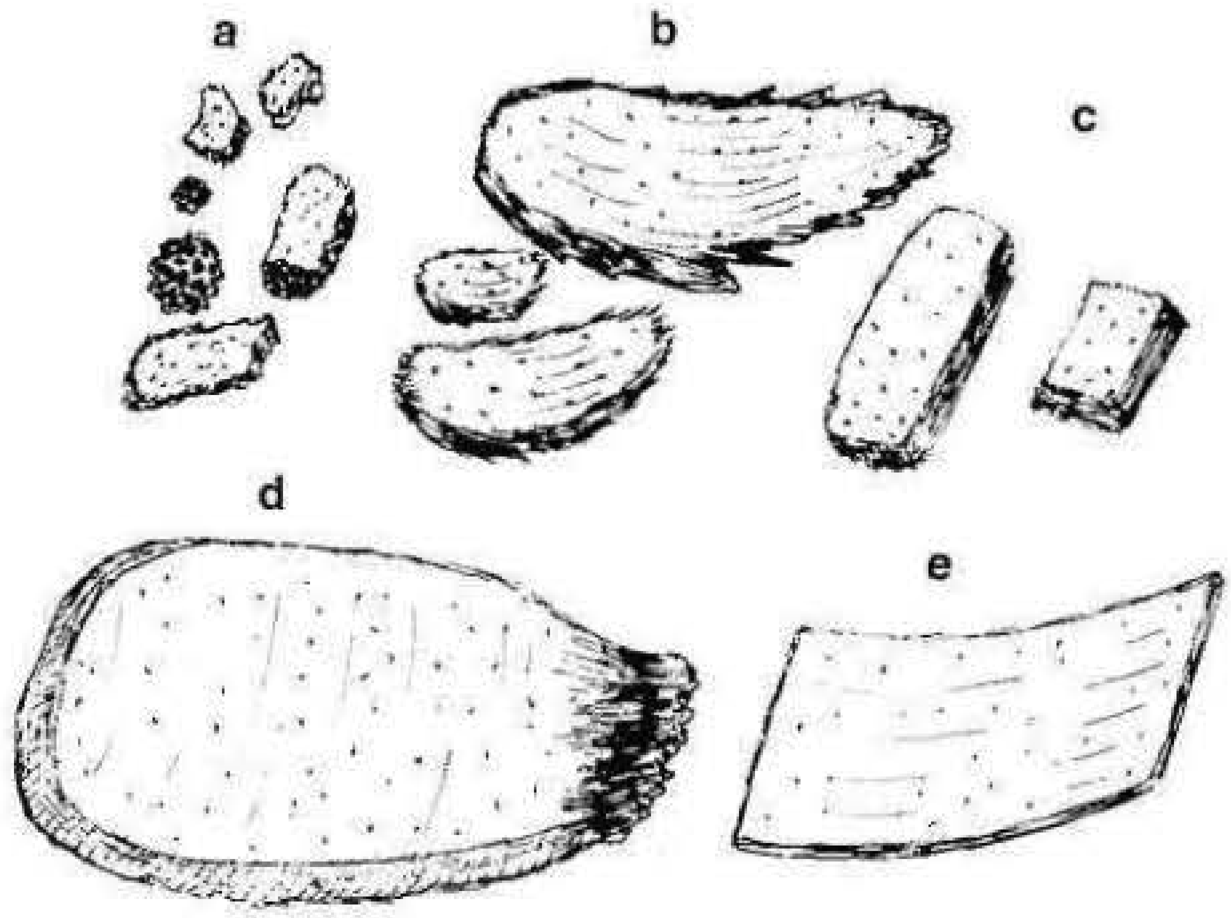


Fig. **999** **Various pieces of orthotopic autogenous bone** from the mastoid process. **a** Bone chips of various sizes, of cancellous bone and of cortical bone. **b** Curled pieces of cortical bone harvested with curved chisels of various sizes. **c** Bony plates harvested with straight, thin chisels, mainly from the edges of the cavity. **d** A large piece of cortical bone harvested as the first piece from the cortex of the tip of the mastoid process. **e** Thin cortical slices harvested with a very thin, straight chisel

Orthotopic Mastoid Bone

Bone from the mastoid process is easily harvested. The present author starts every cortical mastoidectomy by chiseling the mastoid cortex, partly to harvest pieces of bone of various sizes and shape in case they may be needed for ossiculoplasty or obliteration, and partly because using the chisel at this stage is a rapid and efficient way of starting the procedure. If a curved chisel is placed tangentially in relation to the mastoid bone, there is no danger of damaging the sigmoid sinus. Theoretically, the mastoid bone is cancellous and cortical, but practically, very little cancellous bone can be harvested from the mastoid process, especially since bone in contact with cholesteatoma and mucous membrane must not be used. Only cortical bone from the mastoid process is therefore used.

Autogenous cortical bone can be used in various shapes and for various purposes.

1. Bone chips, usually cut with a rongeur from larger bone pieces, are especially suitable for obliteration of deeper parts of the cavity (Fig. **999a**). The term “bone chips” is usually used for cancellous bone in orthopedic surgery, but in otologic literature the term “bone chips” is used for any small piece of bone, or even for larger pieces, which are usually cortical.

2. Curled bone pieces are produced at the beginning of the mastoidectomy using a 4-mm curved rhinoplasty chisel (Pou 1977). The graft is cut fairly thin, so that it curls as it is cut and thus has the contour of the ear canal (Fig. **999b**). The curled bone pieces can be small or large, depending on the size of the curved chisel used. The chisels are placed more or less tangentially to the cortical bone of the mastoid plane. Because the method results in many fractures of the bone, it can easily be divided into smaller pieces.

3. Bone plates are produced with straight chisels of various size, usually along the edges of the cavity. The chisel is placed more or less perpendicular to the cortical bone. The plates can be cut to various sizes and placed in the cavity. The plates are also used for special purposes, e. g., in the attic, to close the communication with the tympanic cavity, or in scutumplasty, as well as in reconstruction of the bridge, attic, or ear canal wall, and also in ossiculoplasty (Fig. **999c**).

4. Large pieces of bone are harvested at the start of the mastoidectomy, usually from the tip of the mastoid process, especially in cases with extensive pneumatization (Fig. **999d**). The large pieces can be shaped for use in reconstruction of the ear

canal wall (Fig. **837, 838**), or placed on the medial wall of the attic as the most meatal part in obliteration.

5. Slices of bone are produced by careful chiseling with an extremely thin chisel (Fig. **999e**), for use in Nakano's reconstruction of the ear canal wall (1993).

6. Bone paté can be harvested by drilling the mastoid process before reaching the mucosa or other pathology within the cells. Bone paté can be collected in many ways using a bone collector, e. g., the Perkins type (Fig. **842**), or industrially-made small bone collectors. The paté can also be harvested without collectors, applying slow-speed drilling on the surface of the bone with very little water. In this way, the bone paté is retained around the site of drilling, and it can then be collected with a spoon-like instrument.

Obliteration with Bone Chips

Bone chips, small bony plates, or small curled pieces of bone, are usually used in combined-graft obliteration (Tos 1977), behind cartilage (Figs. **979, 980**), and in obliteration of a cavity behind an intact ear canal wall (Figs. **381–383**). Palva (1989), however, has used bone chips for reconstruction of the attic wall in obliteration with bone paté (Fig. **1000**). After a canal wall–down procedure for attic cholesteatoma, the ear canal skin remains as an intact tube in Palva techniques. At the end of the operation, the ossicular chain is reconstructed, and the defect in the drum and the ear canal skin adjacent to what was Shrapnell's membrane are covered with an underlay fascial graft extending laterally. The ear canal is then carefully packed with Gelfoam and gauze to maintain its original size. The medial part of the cavity is filled with bone paté. The bone chips and small bony plates mainly obliterate the attic, and are arranged in such a way that they represent the medial wall of the new ear canal. A Palva flap is replaced behind the fascia, and the cavity is filled with bone paté.

Obliteration with Bone Plates

Obliteration with bone plates, curled bone pieces, and bone chips (Shinkawa and Sakai 1990, 1992) involves using large bony plates placed on the medial wall of the attic, posterior to the facial nerve, tightly closing off the connection between the attic and the tympanic cavity (Fig. **1001**). Behind the bony plate, the cavity is obliterated with bone chips and small, curled bone pieces of various sizes. The technique exclusively uses autogenous bone, but a musculoperiosteal flap is placed laterally. Compar-

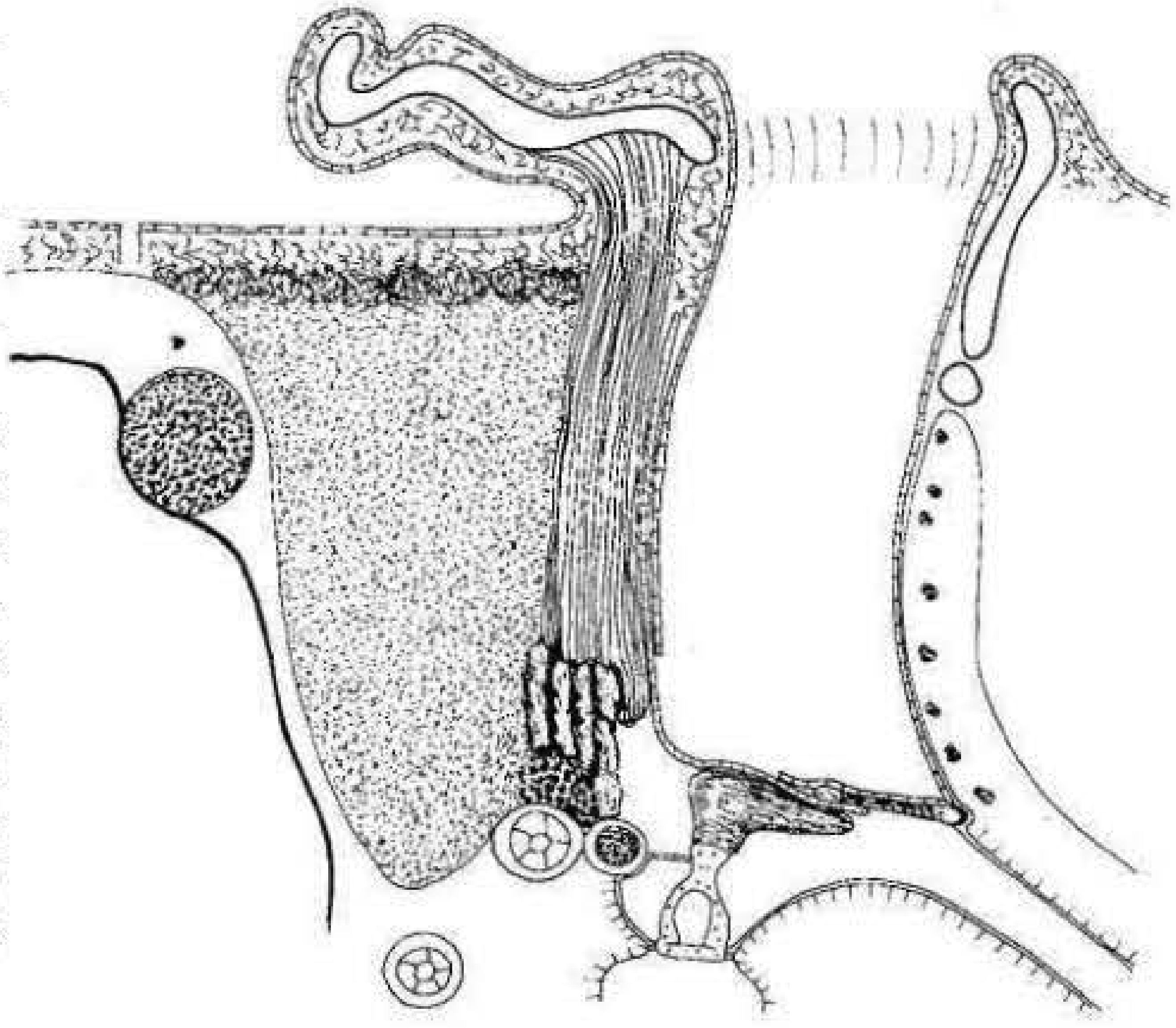


Fig. **1000** **Obliteration with bone chips, curled bone pieces, bone paté, and a Palva flap** (Palva). Bone chips and bone plates are placed medially on the attic wall, forming the medial part of the ear canal wall. The laterai part of the ear canal wall is reconstructed with a large Palva flap and a piece of fascia. Behind the ear canal, bone paté obliterates the cavity. Some Gelfoam covers the bone paté laterally

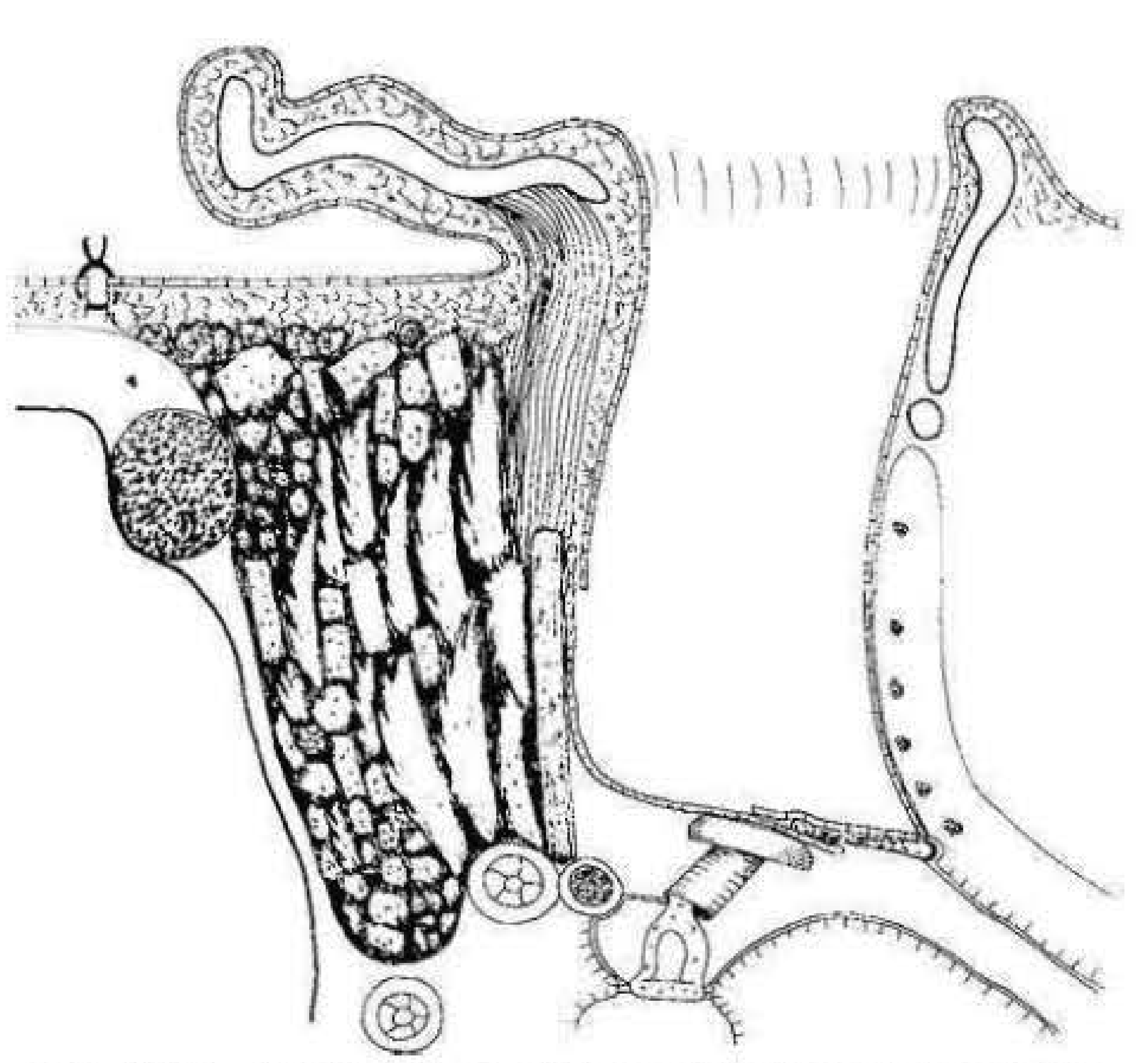


Fig. **1001** **Obliteration of the cavity with bone chips, bone plates and curled bone pieces** (Shinkawa and Sakai). The cavity is filled with bone plates, bone chips, curled bone pieces, or combinations of the three. Meatally, a large bony plate is placed on the medial wall of the attic, representing a new ear canal wall. The Palva flap and bone plates support the lateral part of the new ear canal. The ossiculoplasty is performed using an Apoceram prosthesis

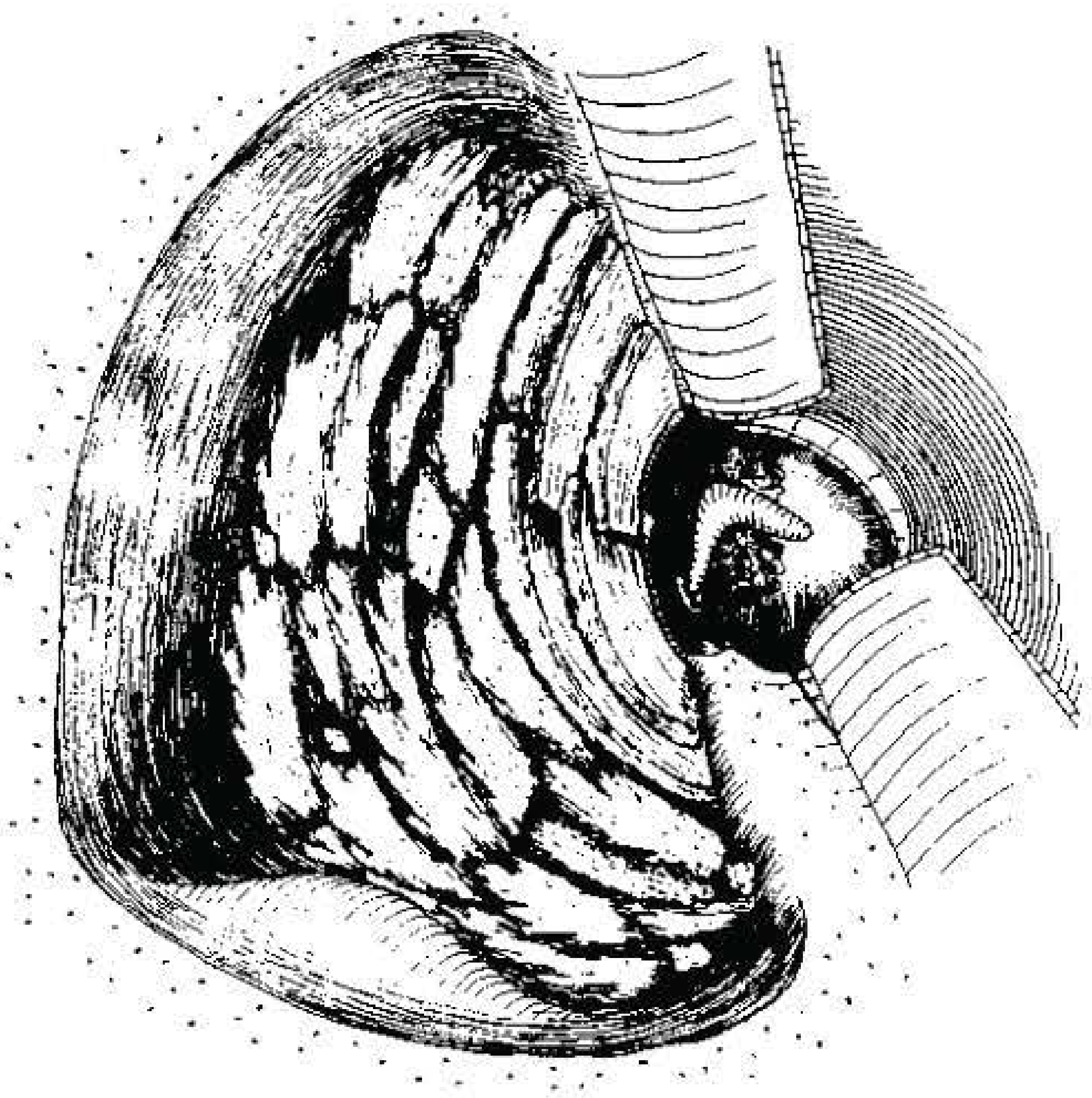


Fig. **1002** **The ear canal wall reconstruction and cavity obliteration with autogenous bone** (Ekvall 1980). Meatally, larger curled pieces of bone are placed on the medial attic wall, representing the new ear canal wall. The cavity is obliterated behind the new wall with bone chips and small pieces of bone

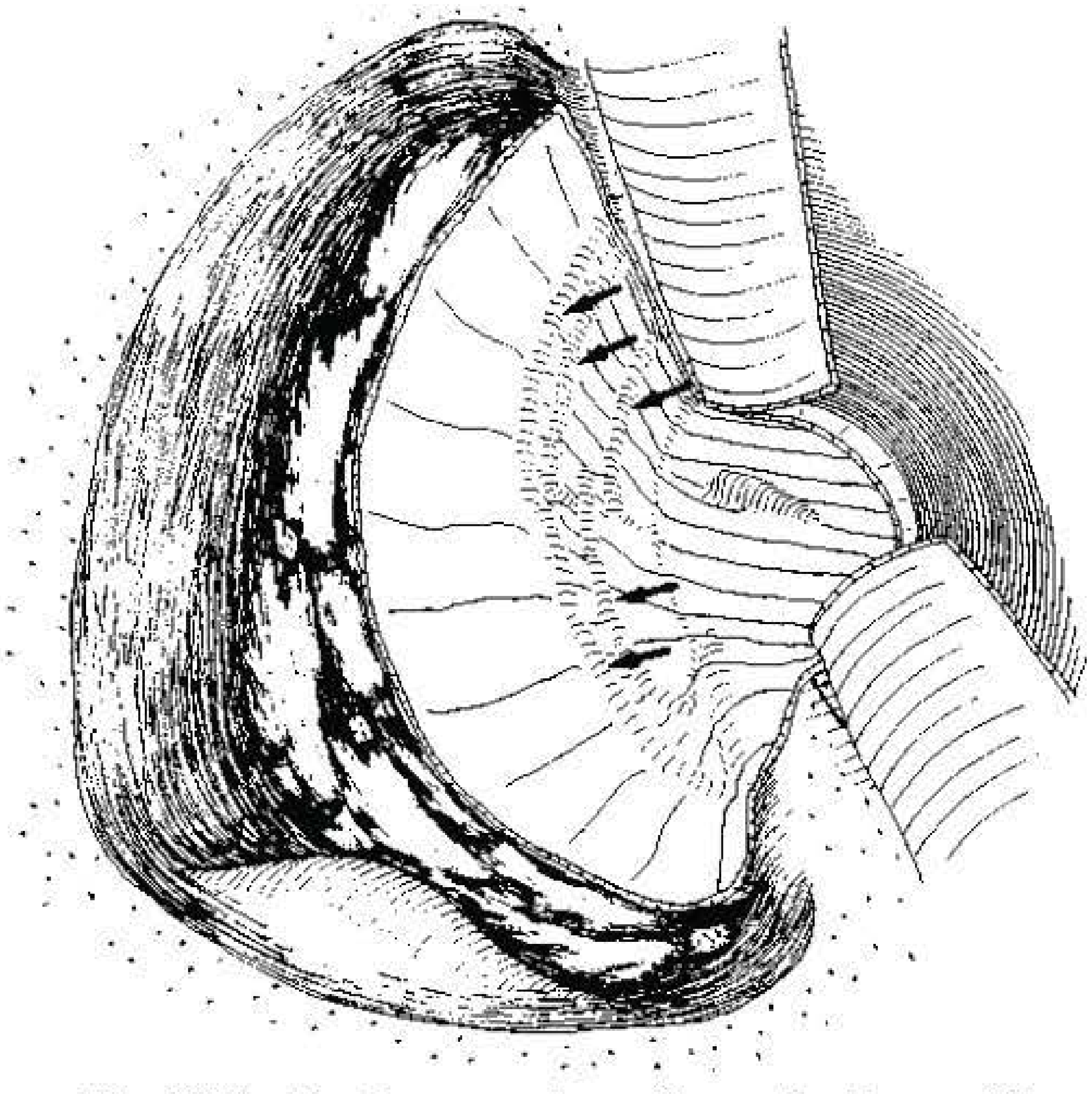


Fig. **1003** Fascia covers the entire perforation and the columella. It extends over the reconstructed bony ear canal. The risk of step formation at the borders between pieces of bone is indicated (arrows)

ing the results in 313 cases treated by obliteration of various types, Shinkawa and Sakai (1990) concluded that use of a muscle flap alone leads to postoperative dilation of the auditory canal. Use of bone paté may aggravate postoperative infection, and this material appeared, in their opinion, to be a poor choice for obliteration when compared to bone chips and small bone plates, which were favored as obliteration materials.

Another method using bone plates and bone chips illustrates the evolution of a personals technique from the reconstruction of the ear canal wall using cortical bone for ventilation of the cavity, through obliteration (Ekvall 1973). A large musculoperiosteal flap, based both superiorly and inferiorly, is elevated, pushed anteriorly, and held in place with a selfretaining retractor (Fig. **836**). Recognizing that ear canal reconstruction with bone and ventilation of the cavity failed to work in many patients, Ekvall (1980) replaced this method with total obliteration of the cavity using bone chips and reconstruction of the ear canal wall with curled pieces of bone and bone slices, with some widening of the ear canal. After placement of a columella (Fig. **1002**), curled bone pieces are placed on the medial wall of the attic in an orderly pattern, initially superiorly, then inferiorly just behind the first one, with the third and fourth pieces placed superolaterally and inferolaterally. At the same time, bone chips are placed behind the new ear canal, in the medial part of the cavity, thus obliterating it before the ear canal is further reconstructed laterally by placing more curled pieces of bone whilst the cavity behind the ear canal is further filled with bone chips. Fascia is used to cover the ear canal (Fig. **1003**). The musculoperiosteal flap (Fig. **839**) is now placed over the lateral part of the reconstructed ear canal wall (Fig. **1004**), and the epithelial flaps are replaced. Laterally, a meatoplasty is carried out, including removal of a large piece of conchal cartilage and the creation of a Körner flap (Fig. **1005**). At the junction between the bone pieces, the new ear canal wall may be irregular, with step formation (Fig. **1003**, **1005**), especially medially, where the reconstructed ear canal wall is only covered by fascia. This may create sharp edges and result in disturbance of migration and crust formation. Recognizing these problems, Ekvall (1987) again modified his obliteration method into a combined-graft obliteration, using large pieces of tragal or conchal cartilage, or both, for the new ear canal (Fig. **1006**). The conchal cartilage is now placed as medially as possible, and the bone pieces, slices, and chips are placed behind the cartilage. The new ear canal wall is covered by fascia and the tympanomeatal flaps. The musculoperi-

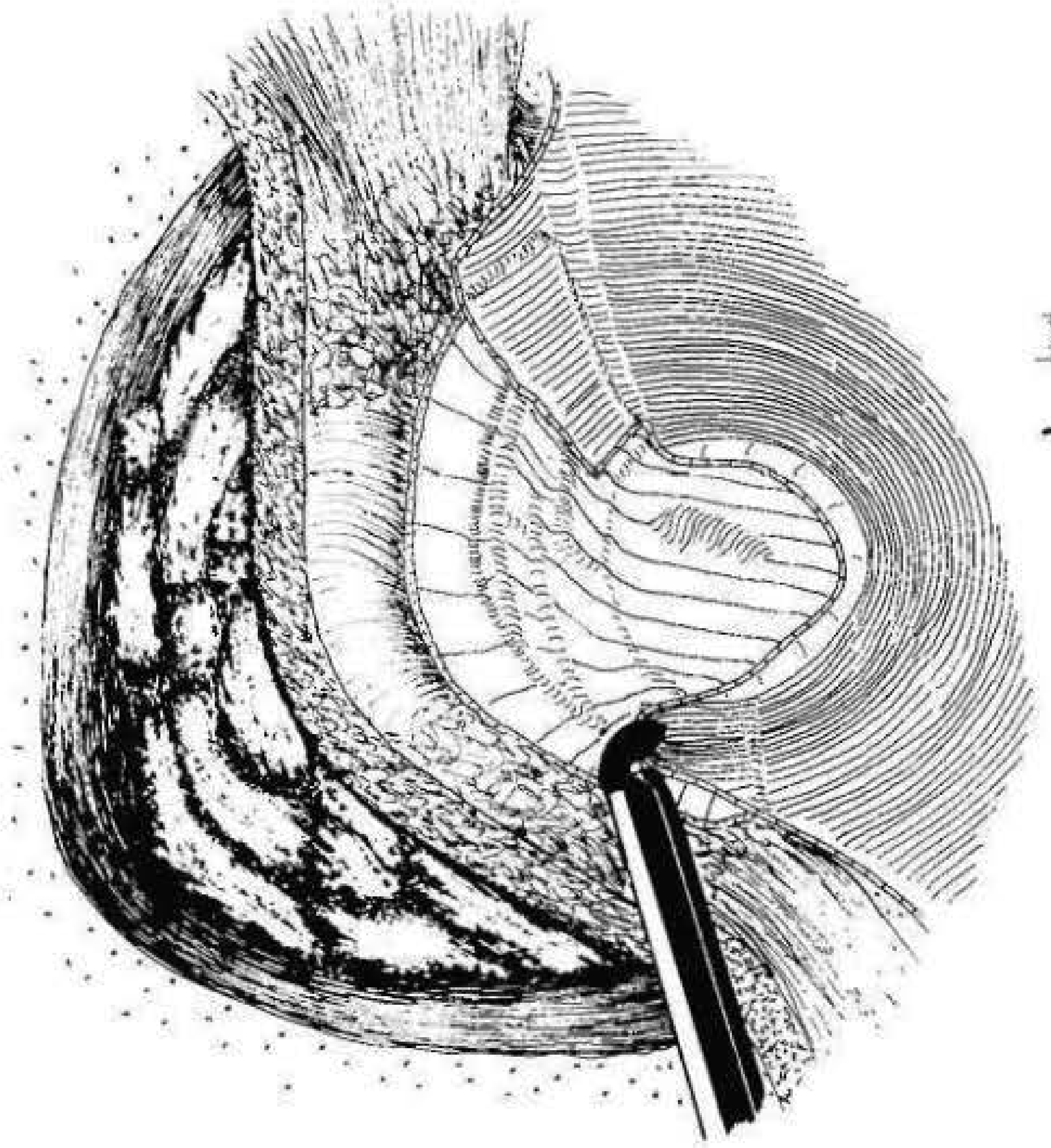


Fig. **1004** The superiorly and inferiorly-pedicled musculoperiosteal flap is replaced, covering the lateral part of the wide ear canal. The fascia and the epithelial flaps are replaced

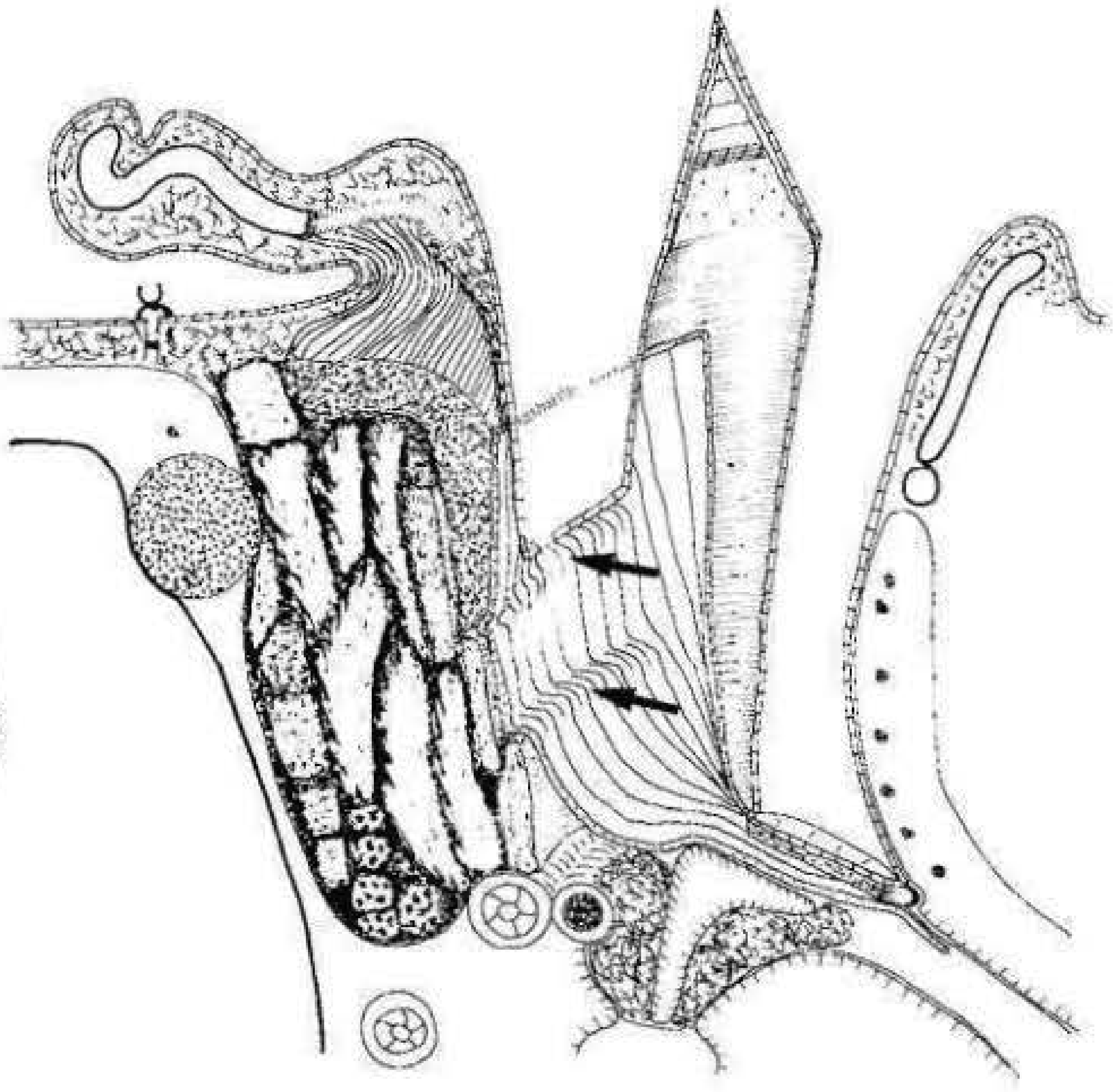


Fig. **1005** Side view, with some perspective, of the reconstruction of the ear canal with bone and meatoplasty. A large piece of conchal cartilage is resected, and a meatoplasty is carried out, widening the ear canal. The cavity is obliterated with bone chips and small bone pieces. The ear canal wall is reconstructed with curled pieces of bone. The fascia covers the new ear canal wall medially, and the musculoperiosteal flap laterally. The border between two bone pieces may be irregular, as in step formation (arrows)

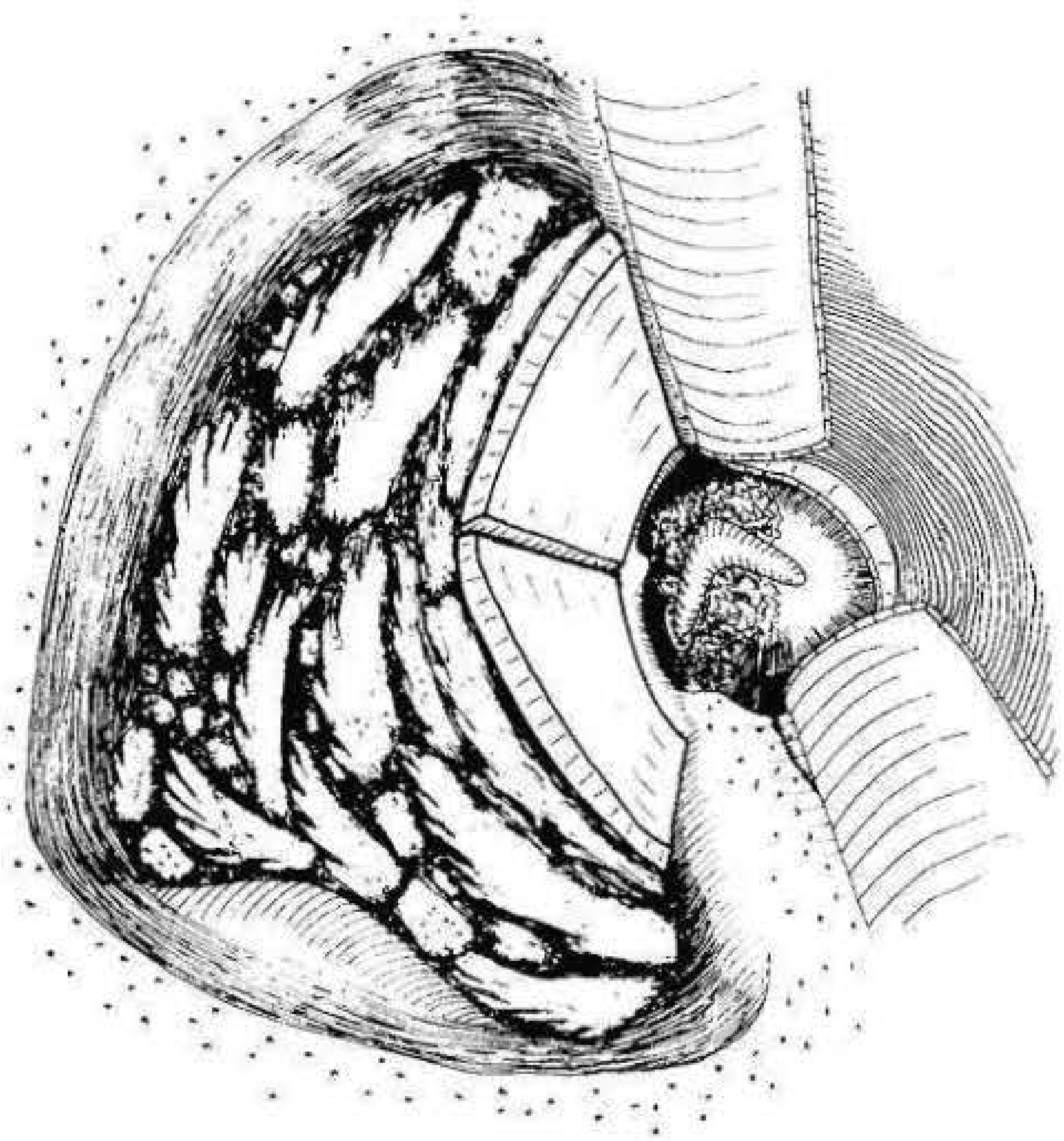


Fig. **1006** **A combined-graft reconstruction of the ear canal wall with tragal and conchal cartilage and obliteration with bone** (Ekvall 1987). Medially, instead of bony plates, cartilage is used to reconstruct the ear canal wall. Bony plates are placed behind the cartilage, and behind those, bone chips. In the tympanic cavity, the total perforation and the columella will be covered with an underlay fascial graft

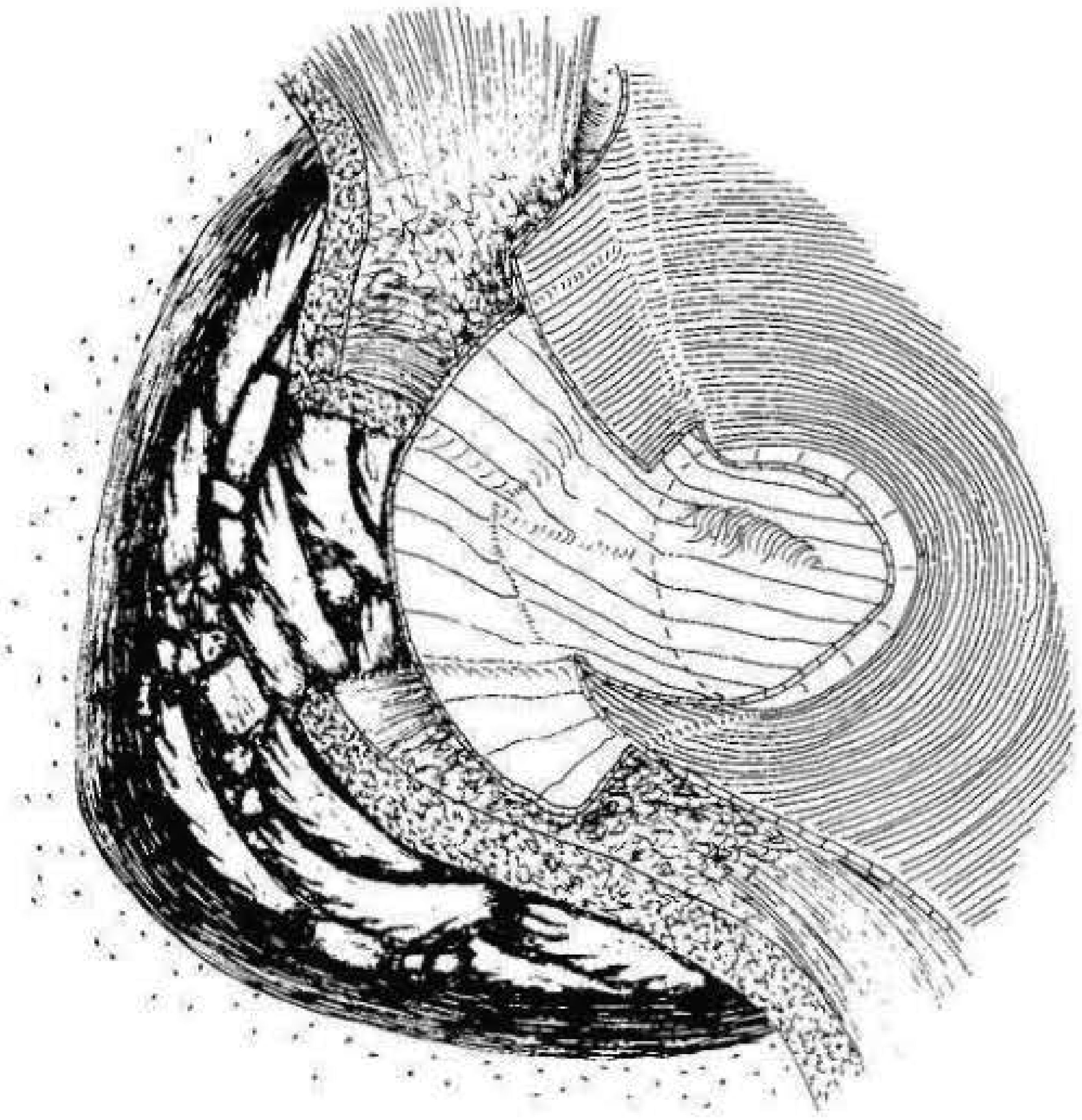


Fig. **1007** A large piece of fascia covers the total perforation and the ossiculoplasty. It extends over the reconstructed ear canal. The musculoperiosteal flap is cut at the 9-o'clock position into two halves, a superiorly-based and an inferiorly-based flap, covering the ear canal superolaterally and inferolaterally. The fascia and the canal skin flap are replaced. The cavity is totally filled with bone chips, and the ear canal is widened by a meatoplasty with extensive removal of the conchal cartilage

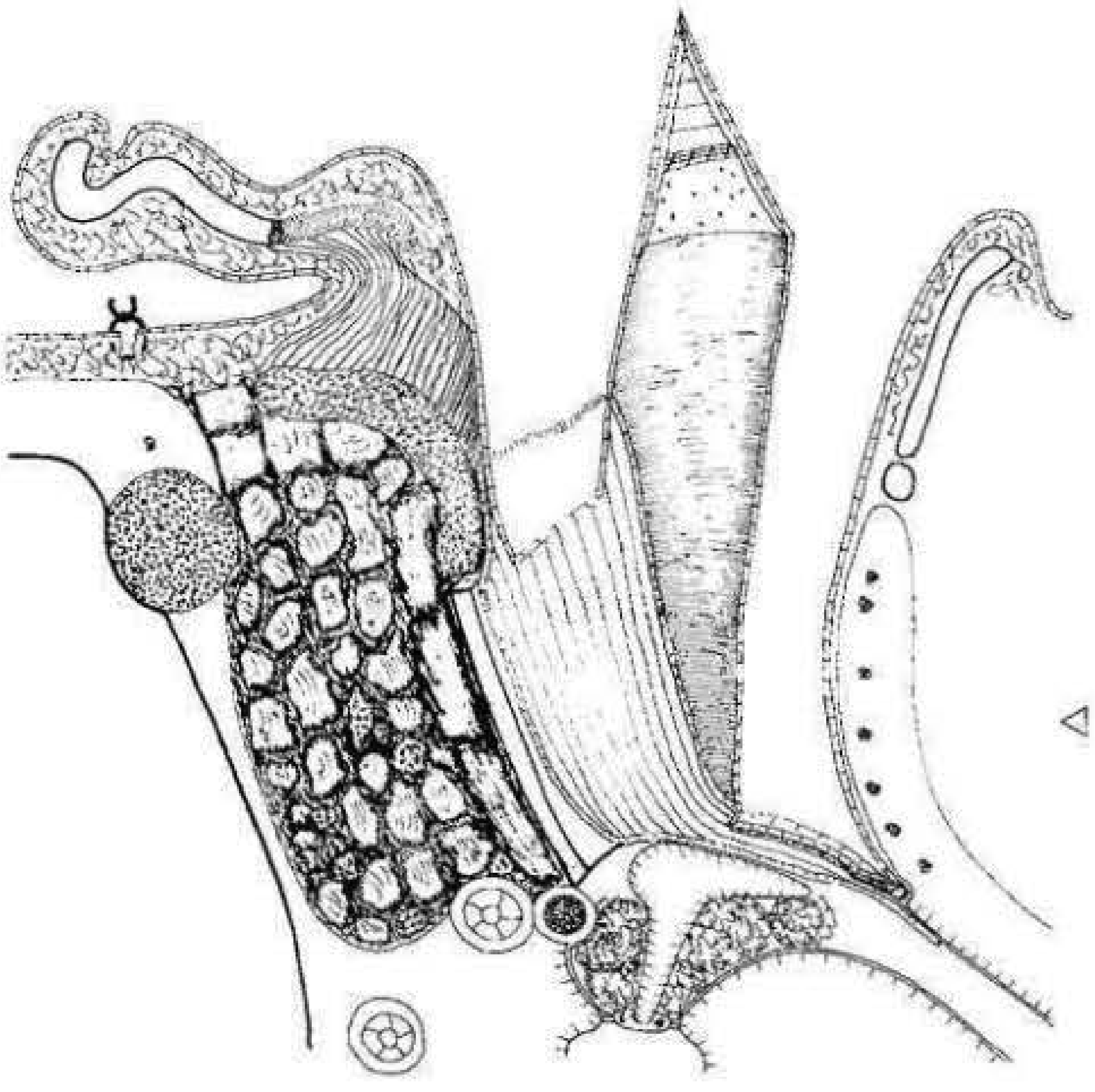


Fig. **1008** Side view of the combined graft obliteration. The conchal cartilage is placed on the medial attic wall, meatal to the bone plates and bone chips. The lateral part of the ear canal wall is formed by the musculoperiosteal flap. The fascia covers the cartilage and the flap. The cavity is obliterated with bone chips and bony plates. The ear canal is widened, and a Körner flap is placed on its lateral part

osteal flap is divided at the 9-o'clock position in order to cover the enlarged ear canal wall (Figs. **1007, 1008**).

The present author does use curled bone plates and bone chips in obliteration, but the bone is never placed medially or directly under the fascia. The bone edges are usually sharp, and the migration properties of the skin in ear canals reconstructed in this way is not always optimal. In addition, infection may occur in retractions and fissures between the bone chips, with epithelial ingrowth, which may be impossible to clear without reoperation. The method described in Figures **1002–1005** has been, and still is, used in several parts of Sweden and Denmark, and the author has therefore had the opportunity of carrying out reoperations on many patients initially treated elsewhere. Experience with reoperations indicates that obliteration and reconstruction of the ear canal wall using autogenous bone alone, without covering the ear canal wall either with cartilage or a Palva flap, creates several problems with retraction, as well as infection of the mucosa between the bone chips. Such cases are impossible to treat without revision surgery. In addition, some bone pieces are resorbed more than others, and in some places excessive new bone formation takes place, resulting — in the long term — in irregularities of the cavity walls.

Obliteration with Bone Paté

Bone paté has become a popular method of obliteration, especially when combined with fibrin glue. The great advantage of bone paté is its ability to smooth out the rough surfaces of the medial walls of the cavity, i. e., in the deep perilabyrinthine cells, deep mastoid tip cells, the sinodural angle, or the exposed facial nerve. Bone paté is therefore often used in minimal partial obliteration in cases of open cavity reconstruction. Bone paté is also used to smooth bone chips and fill out the interstices between the various bone plates, especially on the meatal side of the ear canal wall, and this prevents ingrowth of keratinized squamous epithelium or retraction. Bone paté can be used mixed either with saline, antibiotics, blood, or fibrin glue. Fibrin glue tends to increase the bone paté mass and hold it together as an elastic mass, which is used especially in the obliteration of larger cavities.

Combined-graft obliteration. Bone paté is seldom used alone, and usually forms part of a combined-graft obliteration, essentially because it is difficult to reconstruct the ear canal wall with bone paté. Usually, the bone paté is placed behind tragal cartilage or soft tissues forming the canal wall, but Perkins did describe a method of reconstructing the ear canal using autogenous bone paté (Chapter 17, Figs. **840–846**). Filipo and Barbara placed bone paté mixed with fibrin glue into the interstices between slices of costal cartilage (Fig. **981**).

Palva initially used his subcutis–muscle graft alone, but gradually increased the amount of bone paté in his obliteration techniques (Fig. **1000**). He reconstructed the ear canal wall with bone chips medially and a Palva flap laterally, all covered by fascia. Behind the new ear canal wall, Palva placed large amounts of bone paté. There are apparently no published results for this method.

Honda's method of bone paté obliteration. In old radical cavities and canal wall–down mastoidectomies, Honda (1992) uses bone paté behind fascia or a cartilage plate (Fig. **1009**). The medial wall of the attic is covered with bone paté, thus obliterating the attic separately. First, ossiculoplasty and elevation of a low tympanic cavity are achieved, by placing a ring of septal cartilage on the annulus (Fig. **1009**). The fascia covers the drum perforation and the bone paté, and continues onto the tegmen tympani. A piece of Silastic is placed between the tympanic cavity and the attic. The mastoid cavity is obliterated with bone paté placed behind an autogenous tragal cartilage plate. The tragal cartilage is strengthened with a Palva flap. The bone paté is mixed with fibrin glue. In this method, the attic is either obliterated or left open, the resulting ear canal is wide, and any potential rectraction due to resorption of bone paté does not result in a pocket. This type of a cavity usually remains stable and self-cleaning.

Allogenous Cancellous Bone

Orthopedic surgeons have successfully used small chips of cancellous bone for over 40 years in repairing surgical defects resulting from the removal of cysts and benign tumors from long bones. Although autogenous bone is preferable to homogenous bone, allogenous bone has been used quite satisfactorily by orthopedic surgeons in situations requiring a large amount of bone in which no stress is involved. The situation in the mastoid cavity seems analogous to this, and there is the additional advantage of it being normally occupied by cancellous bone. Schiller and Singer (1960) and Schiller (1961, 1963) have already demonstrated the successful use of cancellous bone for this purpose by using strips of autogenous bone from the iliac crest. Schiller felt that the superiority of autogenous bone in surviving infection is balanced out by the increased morbidity associated with removal of the bone from the iliac crest.

It is convenient to harvest allogenous cancellous bone from patients who are undergoing surgery for trauma, particularly fracture of the femur, in which prosthetic replacement of the femoral head is a routine procedure. In addition, the well-known problems of AIDS and HIV infection are more easily avoided by using surgical material instead of cadavers.

Allogenous bone is seldom used, but there are a few isolated reports of the use of allogenous bone chips and bone paté.

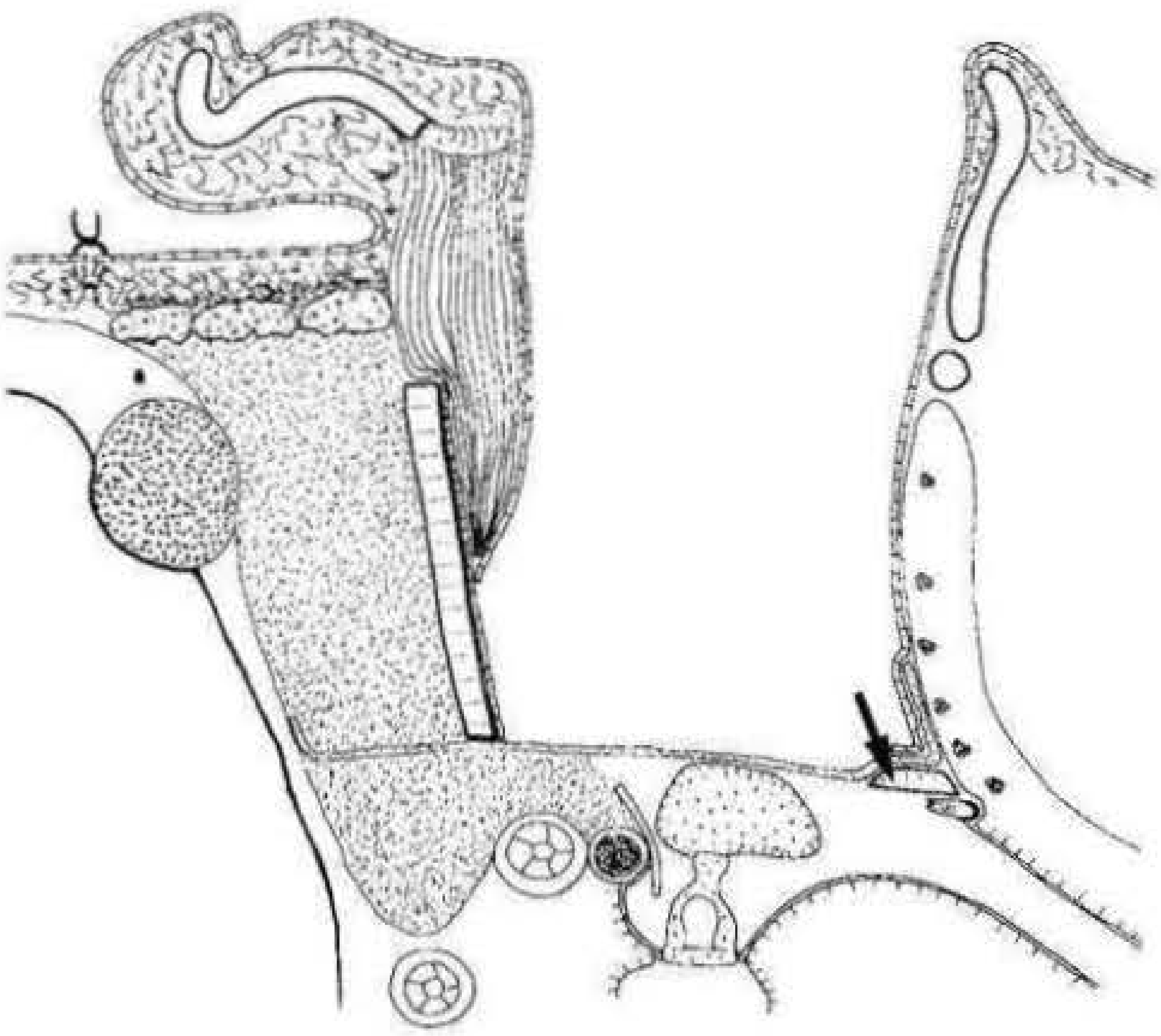


Fig. **1009** **Obliteration of the cavity with a combined graft, including bone paté** (Honda). Bone paté covers the medial wall of the attic and the perilabyrinthine space. A small piece of Silastic separates the tympanic cavity from the attic. A ring of septal cartilage is placed on the fibrous annulus all the way around between the 9-o'clock the and 3-o'clock positions to elevate a low tympanic cavity (arrow). The fascia covers the septal cartilage, the ossiculoplasty, and the bone paté, and it ends at the tegmen tympani. The widened ear canal is separated from the cavity with a large plate of tragal cartilage Laterally, a Palva flap forms the new ear canal wall. All of the mastoid cavity is filled with bone paté and fibrin glue

Shea and Gardner (1970) were the first to use allogenous bone chips to reconstruct a radical cavity. Their technique was as follows. After canal wall–down mastoidectomy and ossiculoplasty, a large piece of fascia is placed as an underlay graft, covering the drum perforation and ossicles. The fascia is fixed with Gelfoam at the level of the medial attic wall, and the epithelial flaps are replaced (Fig. **1010**). The fascia is then turned anteriorly to give the new ear canal a firm wall (Fig. **1011**). The cavity is obliterated with allogenous cancellous bone chips from the head of the femur (Fig. **1012**). The lateral surface and anterior surface of the cancellous bone are then covered by other available autogenous mesenchymal tissue, e. g., fascia, perichondrium, or periosteum (Fig. **1013**). The auricle is restored to its proper position, and the skin is sutured. The ear canal is somewhat widened, and consists medially of two layers of fascia, which is hardly sufficient (Fig. **1014**). The present author would propose placing tragal cartilage as a new ear canal behind the fascia, and use a Palva flap laterally (Fig. **1015**). A firm ear canal is thus created, and the chances of success for the obliteration is, in the author's opinion considerably increased.

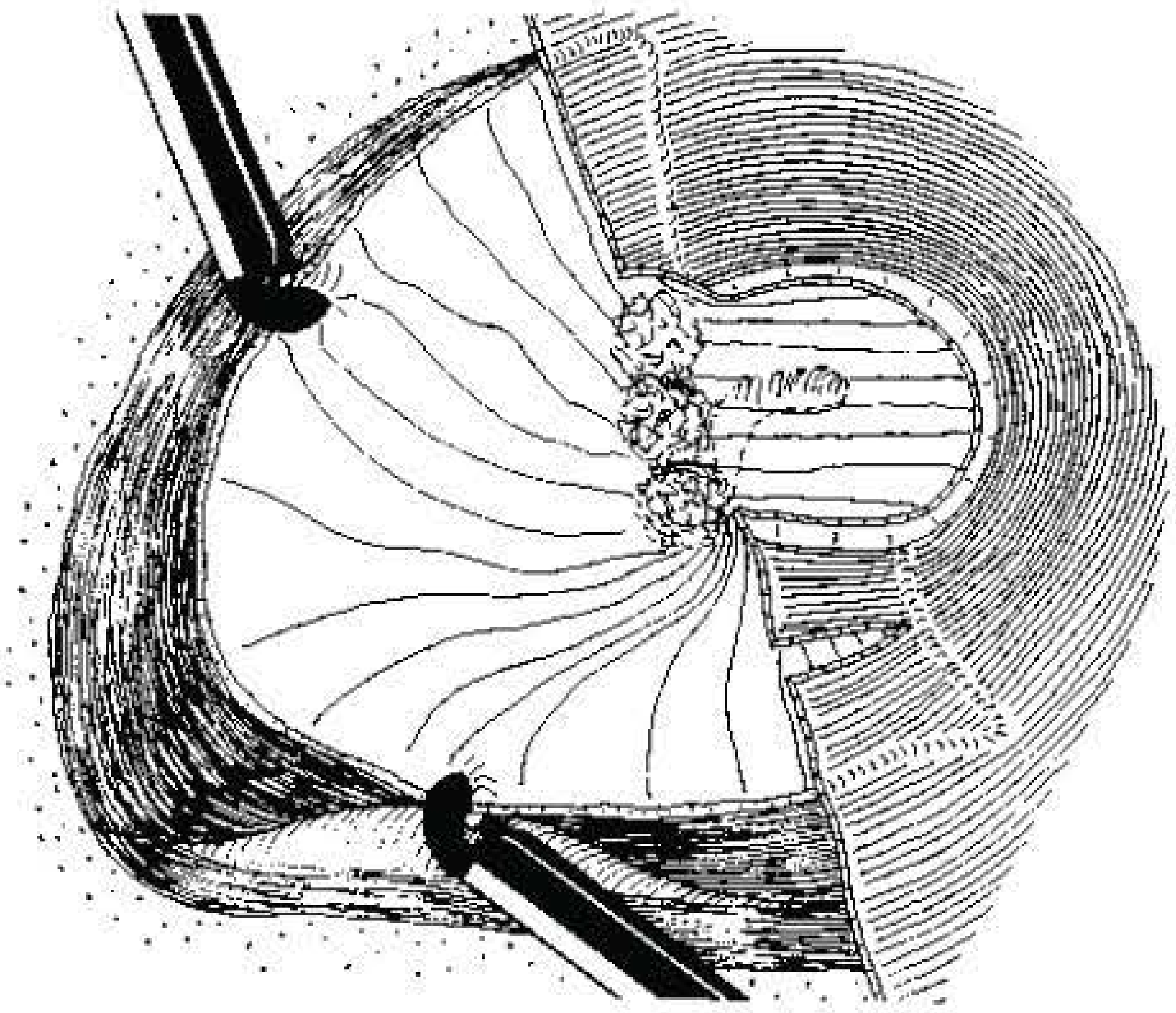


Fig. **1010** **Obliteration of the cavity using allogenous cancellous bone chips** (Shea and Gardner). An ossiculoplasty with a columella is carried out, the total perforation is closed with an underlay fascial graft, and the skin flaps are replaced. Using two forceps, the fascia is turned anteriorly, forming the new ear canal

Shea and Gardner (1970) reported good results for obliteration of the cavity in a series of 13 cases followed up maximally for three months, but there are no late results published for this method to demonstrate whether the bone is resorbed or not.

It has been shown experimentally (Preobrazhensky 1977) that the transplantation of crushed bone into the infected bulla of a rabbit can be successful if there is careful surgical asepsis, complete removal of the mucosal lining, continuous drainage of the wound during the first few days after surgery, and primary contact with autogenous soft tissue. Ten days after the operation, collagen fibers and proliferation of fibroblasts are observed. Fifteen days after surgery, the new connective tissue is mature, with osteoblasts and the formation of osteoid tissue around the transplanted fragments.

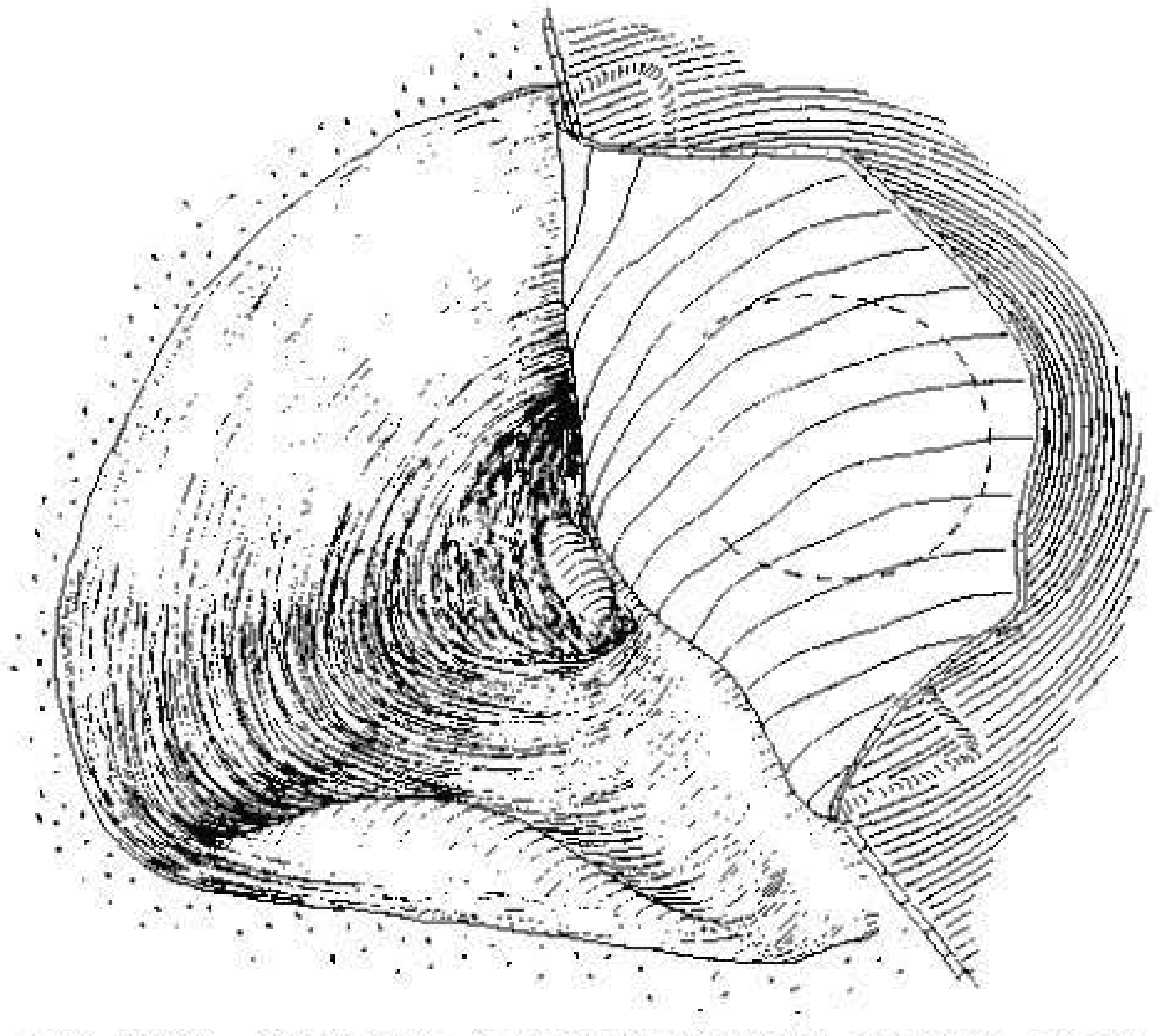


Fig. **1011** The fascia is pulled anteriorly, creating a new ear canal

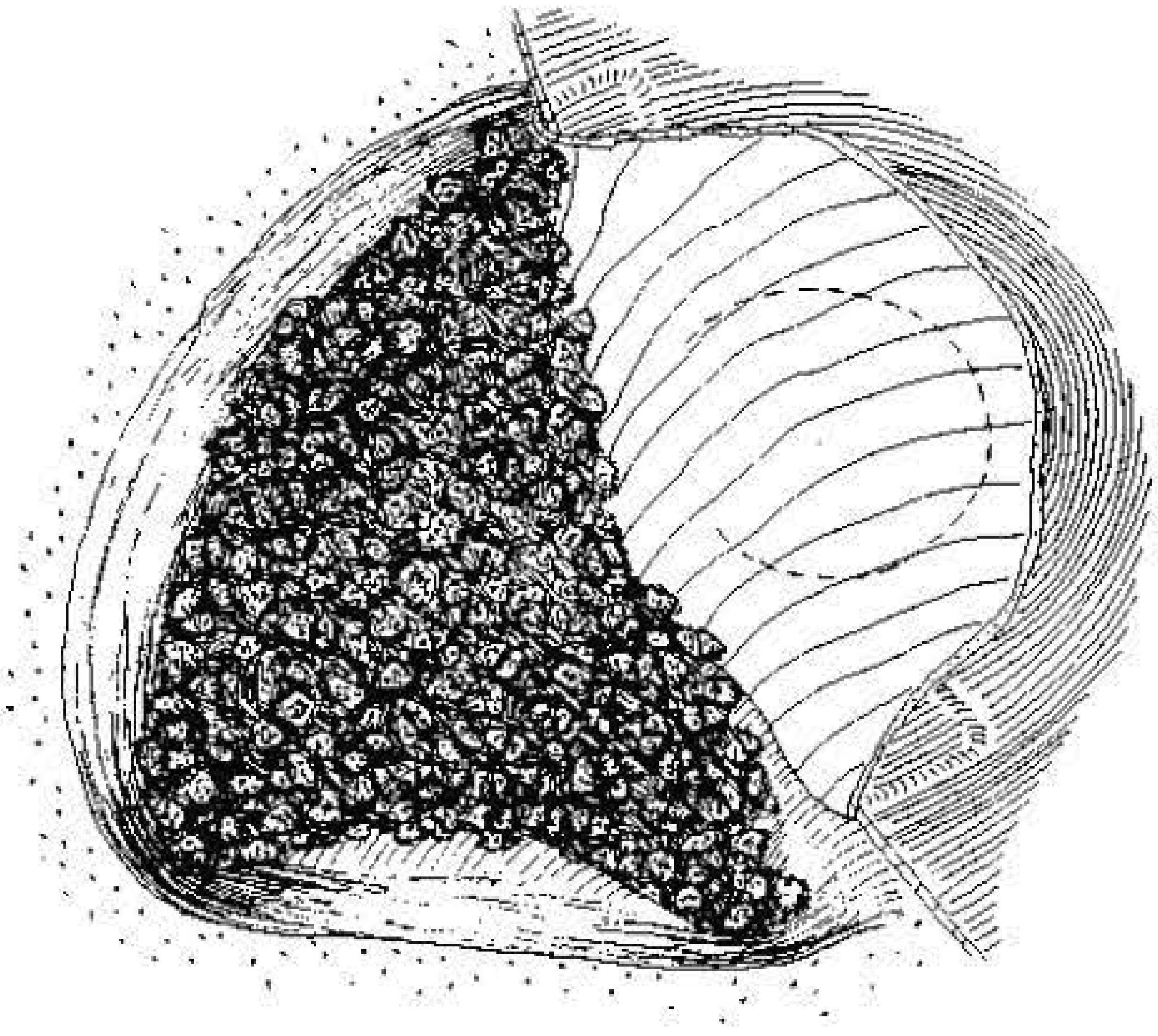


Fig. **1012** The cavity is filled with allogenous cancellous bone chips

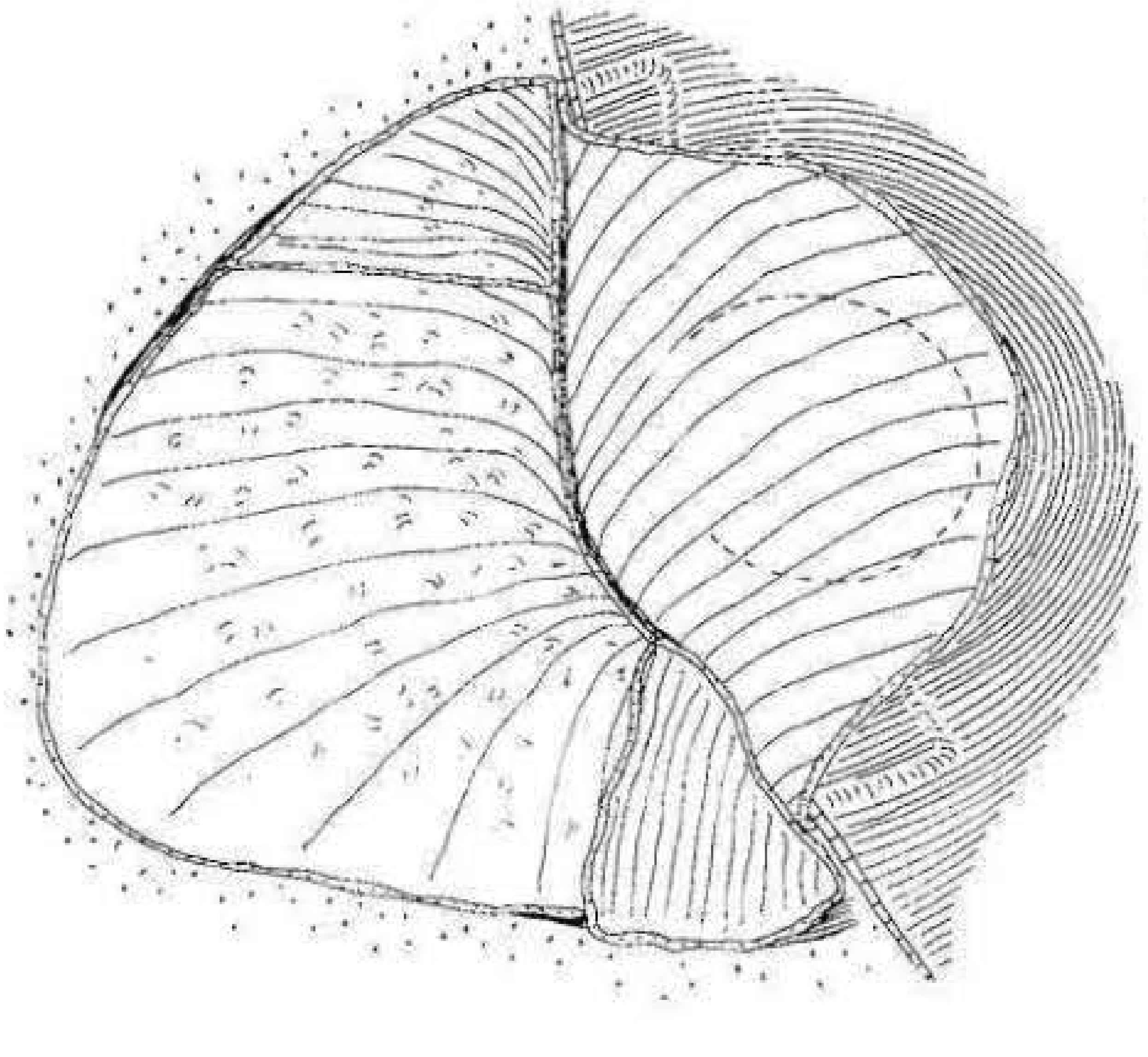


Fig. **1013** All available mesenchymal tissue, either perichondrium, fascia, or remnants of the periosteum, cover the cancellous bone, further separating it from the ear canal

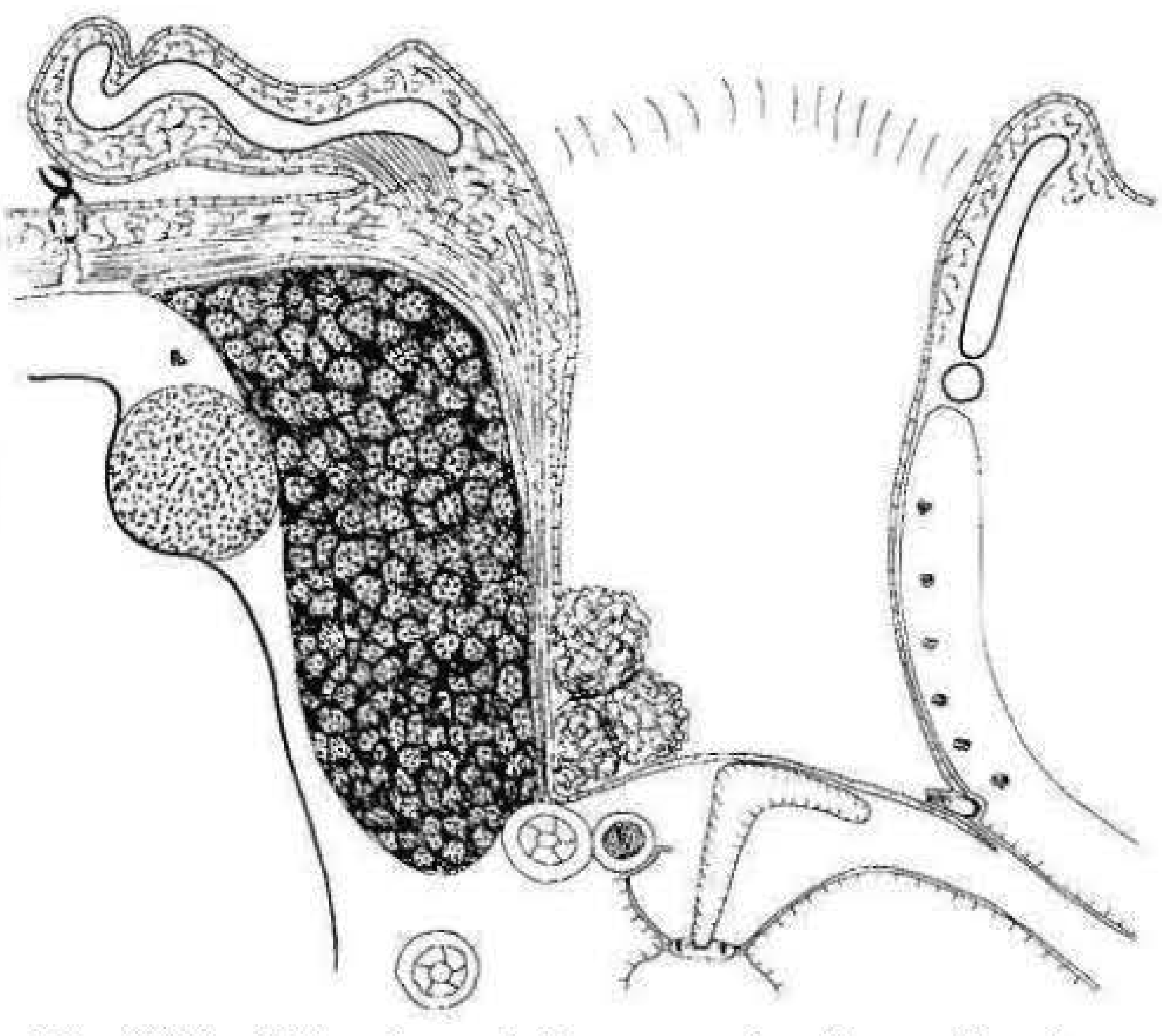


Fig. **1014** Side view of the reconstruction with allogenous bone chips. The fascia covers the columella. It is fixed onto the medial wall of the attic, and then runs laterally, forming the ear canal. The epithelial skin flaps are replaced. Behind the fascia, another membrane of fascia or perichondrium further separates the bone chips from the ear canal

The fragments are gradually resorbed, and are replaced by newly formed bone.

Comparing the five-year results of obliteration using allogenous bone chips from the head of the femur in 50 patients with a similar series obliterated with allogenous cartilage, Preobrazhensky (1977) preferred formaldehyde-stored septal, conchal, or tragal cartilage to allogenous cancellous bone, because the cartilage is easy to apply, possesses good osteogenic stimulating properties, and is not resorbed under the influence of soft tissue. The late results are more stable than after obliteration using allogenous cancellous bone.

The common features in the reconstruction of the ear canal wall and in obliteration using autogenous or allogenous bone are the sharp edges of the new ear canal wall, facilitating crust formation and infection in the ear canal. In addition, the bone may be resorbed and the cavity may be enlarged. In contrast to a cavity obliterated with soft tissues, this type of cavity is irregular and difficult to clean in the long term. In the author's opinion, therefore, the meatal side of the ear canal wall, if reconstructed with bone, should be covered by a thick layer of autogenous mesenchymal tissue.

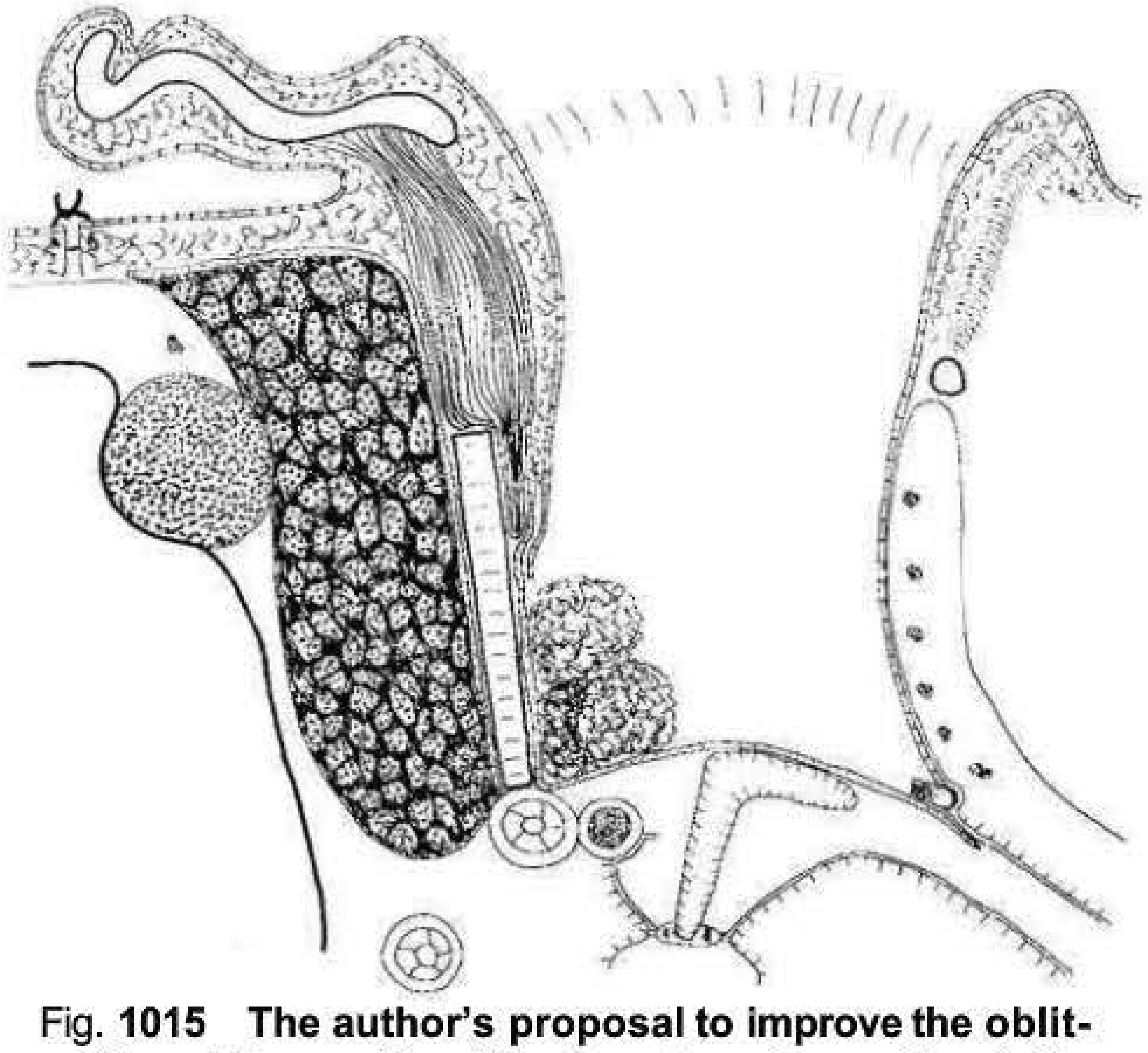


Fig. **1015** **The author's proposal to improve the obliteration of the cavity with cancellous bone chips** (allogenous, or preferably autogenous). A piece of tragal cartilage is placed on the medial wall of the attic, and laterally, a Palva flap forms the ear canal wall. A large piece of fascia covers the tragal cartilage and the muscle, and behind the cartilage further mesenchymal tissue is placed to separate the bony chips from the ear canal wall

21 Obliteration with Biocompatible Materials

Various methods have been published using more or less biocompatible materials to fill the mastoid cavity. These include inorganic bovine bone (Härmä and Koskinen 1965) methylmethacrylate or nonresorbable plastic bone cement (Palacos R) (Mahony 1962, Meuser 1980, 1982, 1983), various ceramics, such as plaster of Paris (Högset and Bredberg 1986, 1988, 1992), tricalcium phosphate (Zöllner and Brüssing 1986), plasticine (Wullstein et al. 1979), Triosite (Gersdorff and Robillard 1987, Olaizola et al. 1989), hydroxyapatite (Hörmann and Donath 1987, Yanagihara and Hinohara 1989, Takahashi and Nakano 1990, 1992, Yanagihara et al. 1993) and glass ionomer cement (Geyer and Helms 1992).

Inorganic Bovine Bone

As early as 1965, Härmä and Koskinen filled the mastoid cavity in 47 patients with bovine cancellous bone treated with ethylenediamine, which removes all the organic substances. The ear canal was reconstructed using a Palva flap (Fig. **1016**), and the space behind the reconstructed musculoperiosteal ear canal was filled with Ossar granules (Lääke Oy, Turku, Finland). Six to twelve months postoperatively, none of the ears required revision surgery due to infection caused by inorganic bone granules. The external auditory meatus retained its shape, and a cavity did not form behind the ear canal. Histological examination revealed new bone formation surrounding the Ossar granules. Even though this method was highly recommended by the authors, nobody apparently has used it since, and no further results have been published on the method.

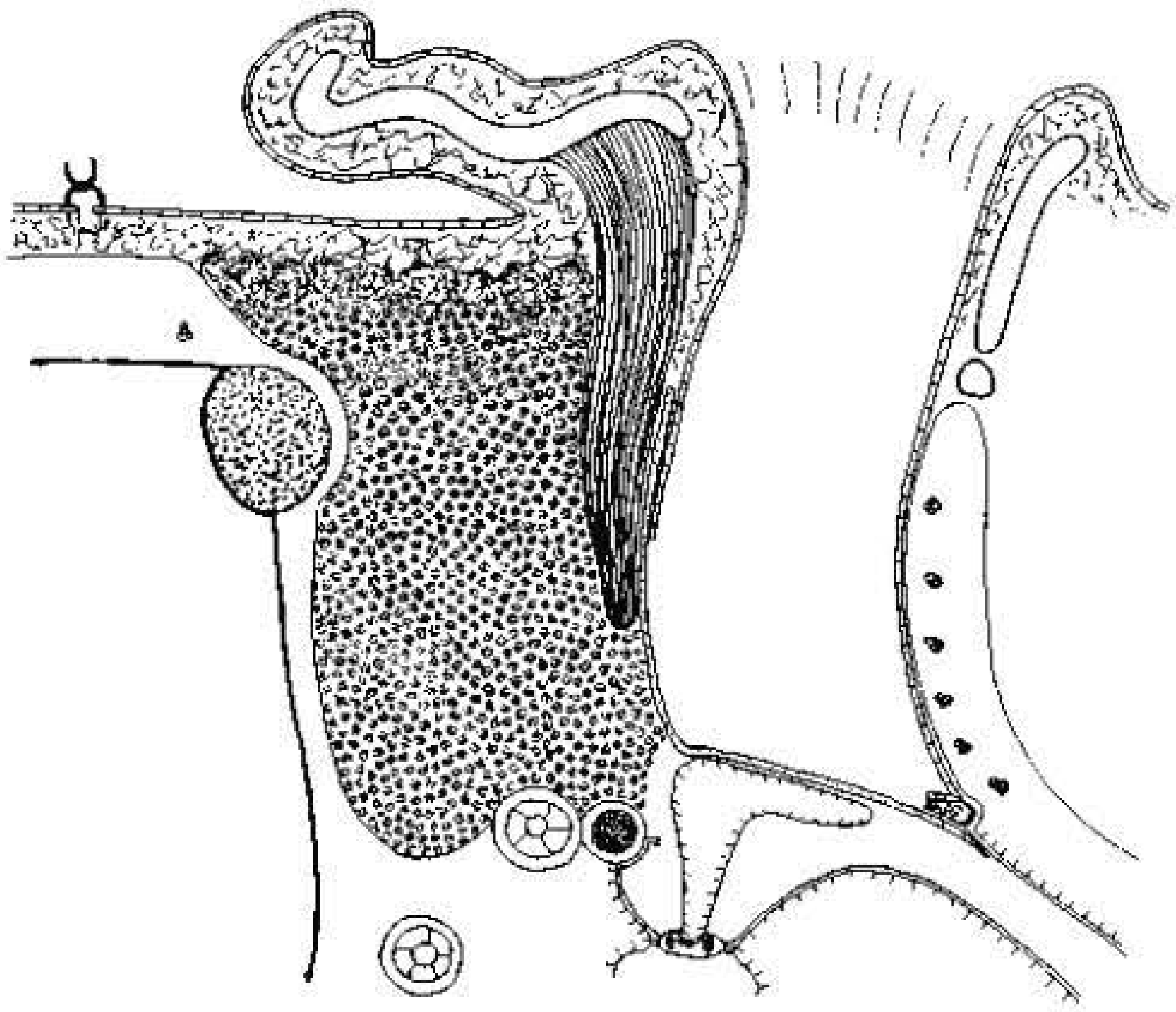


Fig. **1016** **Obliteration of the cavity using anorganic bovine bone behind a Palva flap and a fascia** (Härmä and Koskinen). The ossiculoplasty is performed using a columella. Fascia is placed as an underlay graft, covering the lateral part of the Palva flap. Laterally, the granules are covered with Gelfoam

Ethylenediamine removes all the organic substances from the bovine cancellous bone, leaving only the inorganic material, closely resembling the currently used hydroxyapatite granules.

Obliteration with Methacrylate

As early as 1962, Mahony published on "tympanoacryloplasty," i. e., filling the cavity with methacrylate. Meuser (1980, 1982, 1984) further elaborated on this method by filling the cavity with a nonresorbable methacrylate Sulfix-6 plastic material (manufactured by Sulzer Brothers, Winterthur, Switzerland). With a retroauricular approach, the epithelial lining of the cavity is carefully elevated, preserving as much of the skin as possible. The cavity walls are polished with a diamond burr, and an ossiculoplasty is performed. In order to separate the ear canal from the cavity, a large piece of autogenous conchal cartilage is placed on the medial wall of the attic (Fig. **1017**), and the cavity is filled with methacrylate. The position of the cartilage is secured by fibrin glue. The methacrylate is made by mixing liquid and powdered components, and this mixture is put into a syringe and injected into the mastoid cavity behind the cartilage. It adapts precisely to the cavity. As it hardens, Sulfix-6 produces heat, which can be conducted away by irrigation with a cold saline solution for about eight minutes. Meuser (1982) called this material "plastic bone cement." Early results using this method on 16 ears showed good healing, but in one ear subsequent reobliteration was required. As well as removal of a large piece of conchal cartilage, a meatoplasty is performed, thus widening the ear canal (Fig. **1017**). The acrylic bone cement is not biocompatible, and acts in the long term as a foreign body. In the short term, however, the cement is able to plug the cavity effectively and prevent recurrent cholesteatoma.

No other surgeons have apparently used this method, and Meuser himself later used allogenous costal cartilage for obliteration of the cavity (Meuser 1989, 1993).

Ceramics

Ceramics are inorganic crystalline materials. Over the last 15 years, they have been used in otology, initially as an ossiculoplasty material, and over the last eight years as a material for reconstructing the ear canal wall and obliterating the cavity.

Some ceramics, such as alumina ceramics (Frialit and Bioceram, Vol. 1, pp. 289–291) are nondegradable and *bioinert,* having no biochemical influence on the surrounding tissue. These ceramics are used in ossiculoplasty.

Most ceramics *are bioactive.* They provoke bone formation on contact with the cavity walls. Calcium sulfate ceramic material (plaster of Paris) is used in obliteration, but it resorbs more rapidly as the newly formed bone appears. The calcium phosphate ceramics are used both in obliteration and ossiculoplasty. Porous tricalcium phosphate ceramics and calcium phosphate ceramics are used only in obliteration. They have a slow degradation rate, and are replaced after 12–18 months by newly formed bone.

Bone minerals consists of several calcium phosphate salts, of which the most important is hydroxyapatite. Together with calcium and phosphorous in serum, they form a dynamic equilibiium. Due to an interaction with hydroxyapatite (the calcium–phosphorous system), implants of calcium phosphate soon develop a thin layer of biological apatite, which forms a solid bond between the implants and the bony tissue of the host. Various calcium phosphate ceramics degrade in different ways, depending on their different crystal and chemical makeup, their structure, and the biological activity of the host tissue. Hydroxyapatite implants have shown good biocompatibility (Kuijpers 1984). The outcome of obliteration using pieces of resorbable tricalcium phosphate ceramics has not been conclusive (Zöllner and Brüssing 1986).

Glass ceramic contains silicon dioxide, which is a fine-grained material composed of alkaline silicates and calcium phosphate. Even though it is not degradable, it results in direct bone contact between the implant surface and the host bone through the leaching of calcium and phosphate ions. This material has been used in middle ear reconstructions, for example in Ceravital (Xomed) (Reck 1985).

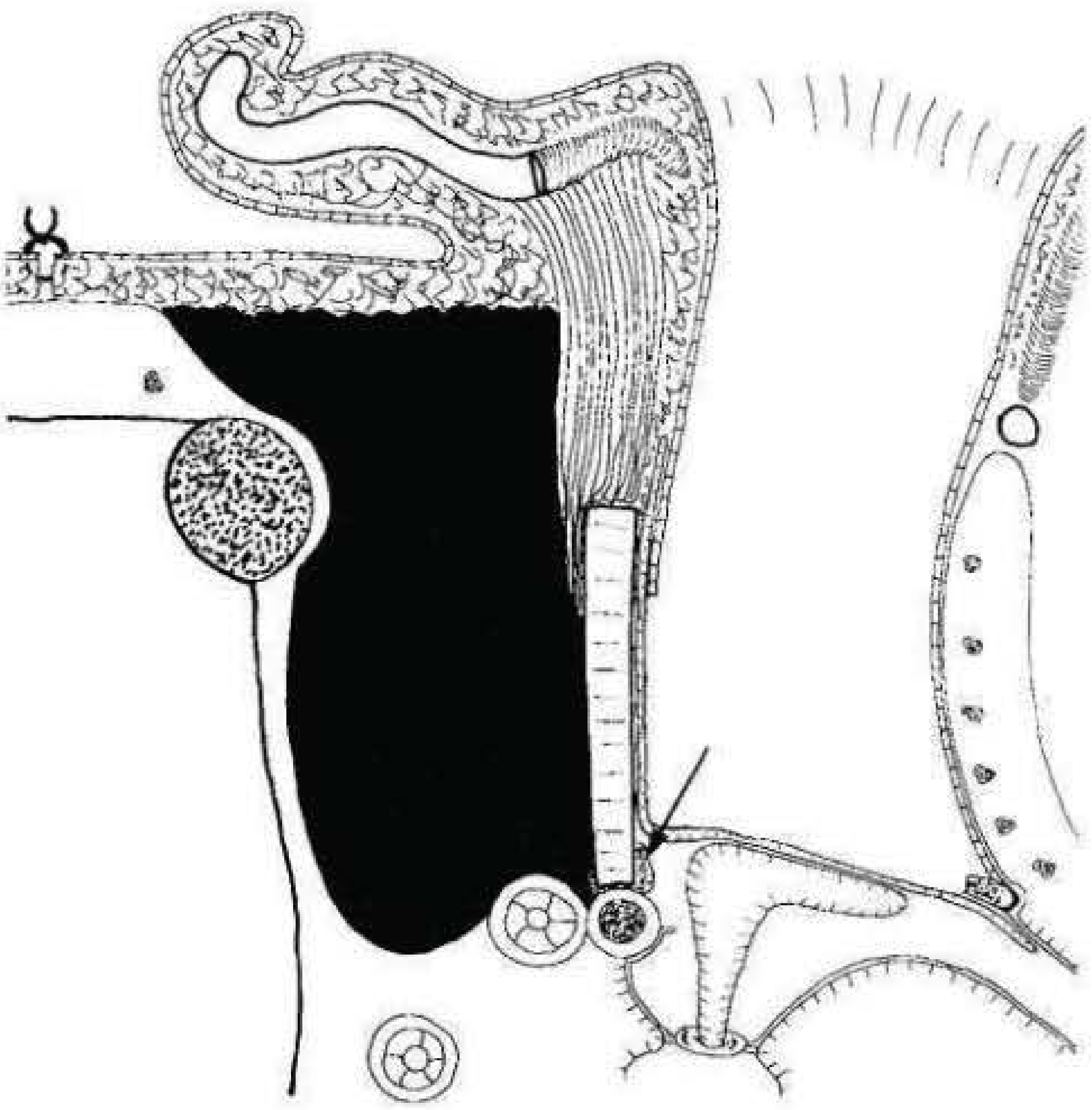


Fig. **1017 Obliteration of the cavity using methacrylate or plastic bone cement** (Meuser). The ear canal wall is reconstructed using autogenous conchal cartilage, sealed to the bony cavity walls with fibrin glue (arrow). The Palva flap is placed laterally. The ossiculoplasty is performed with a columella. Fascia covers the drum perforation as underlay graft. Bone cement is placed behind the reconstructed ear canal. The conchal cartilage is removed, enlarging the ear canal

Plaster of Paris

Plaster of Paris is a biodegradable ceramic material prepared from calcium sulfate, which when mixed with water makes a paté that solidifies within minutes, producing a certain amount of heat as it does so. It is easily applied to the cavity, and its subsequent transformation into a firm block enhances the reconstruction of the posterior ear canal wall.

Plaster of Paris was occasionally used by orthopedic surgeons and dentists in the 1930s and 1940s, with variable results. In 1980, Coetzee obliterated the mastoid cavity using plaster of Paris behind a reconstructed ear canal wall made of allogenous septal cartilage.

In a series of experimental studies on guinea-pig ears, Högset and Bredberg established that plaster of Paris is gradually absorbed and incapable of thermal damage. The tissue response to plaster of Paris in guinea-pig bullae is as benign as that to autologous bone, indicating excellent biocompatibility (Högset and Bredberg 1986). It does not damage the inner ear or cause sensorineural hearing loss (Hog-

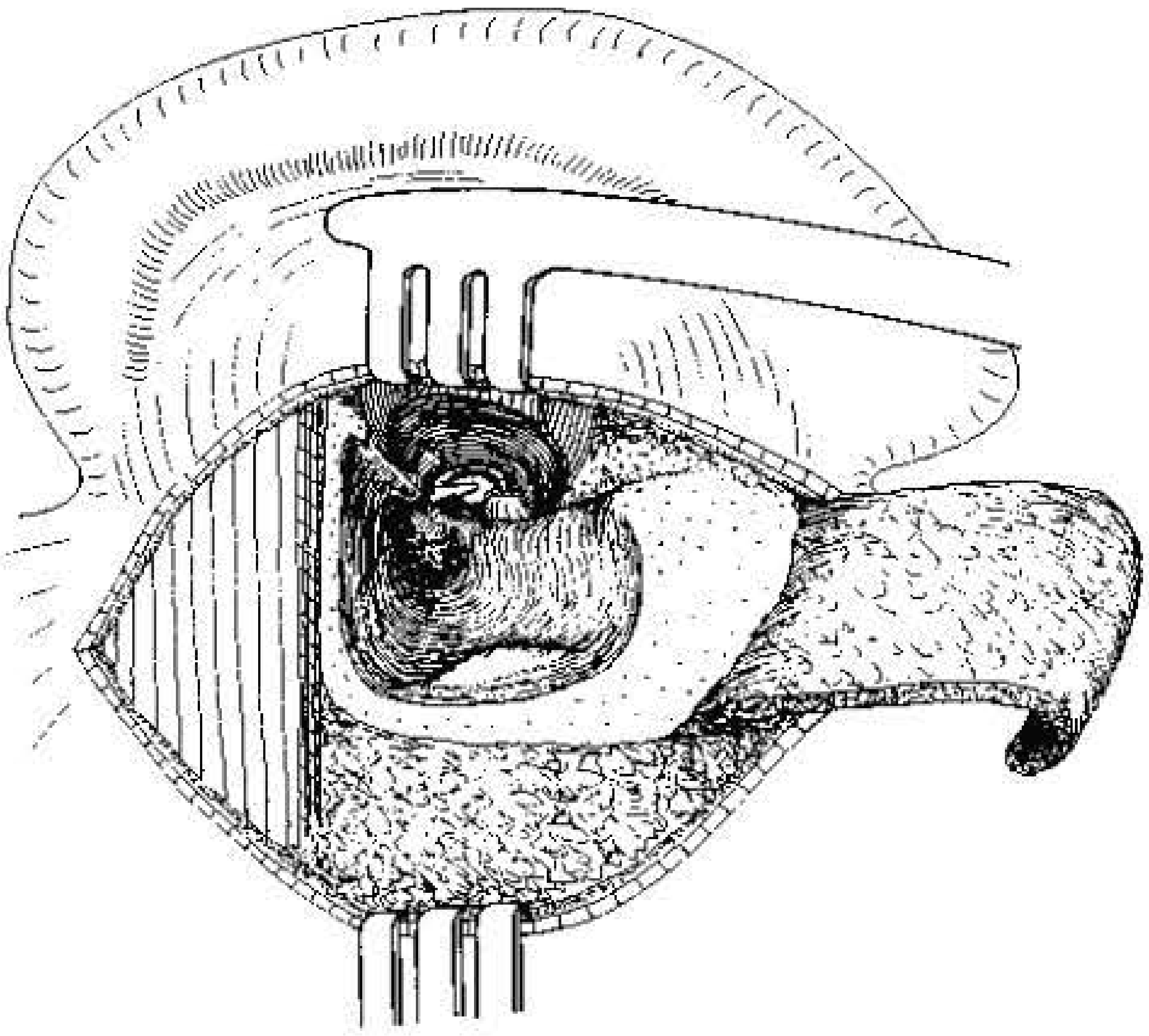


Fig. **1018** **Obliteration of the cavity using plaster of Paris** (Högset and Bredberg). An inferiorly-based subcutis—muscle–periosteum flap is raised, inferior and superior ear canal skin flaps are elevated, and a canal wall–down mastoidectomy is performed

set and Bredberg 1988). It has a bone-stimulating capacity, and the bone formed in its presence has a normal structure. Four to six milliliters of plaster of Paris are needed to obliteratate a radical mastoidectomy cavity that does not exceed the physiological range.

The following technique has been used in 20 patients (Högset and Bredberg 1992). With a retroauricular incision, an inferiorly-pedicled flap is raised from the periosteum, muscle, and subcutaneous tissue overlying the mastoid cortex (Fig. **1018**). The flap is later rotated into the external ear canal. The meatal skin is elevated and displaced anteriorly, creating inferior and superior ear canal skin flaps, as well as a lateral flap. After removal of the pathological lining of the mastoid cavity and polishing of the cavity walls, the ear canal wall is reconstructed. Along the superior cavity wall and the facial ridge, grooves are made in order to place pieces of cortical bone tightly in position. One to three large pieces of cortical bone are used to reconstruct the ear canal wall. The new bony meatal wall is fixed posteriorly with plaster of Paris, easily injected with a syringe because of its initial fluid, paté-like state (Fig. **1019**). Approximately 4–6 ml are used to obliterate the cavity (Fig. **1020**). The bony defect in the mastoid surface is covered with pieces of cortical bone supported by the plaster (Fig. **1021**). After ossiculoplasty, the perforation is closed with a large fascial graft extending over the reconstructed ear canal wall, as well as the musculoperiosteal flap (Figs. **1022, 1023**).

Postoperative follow-up of 20 patients for at least one to five years (mean three years) after

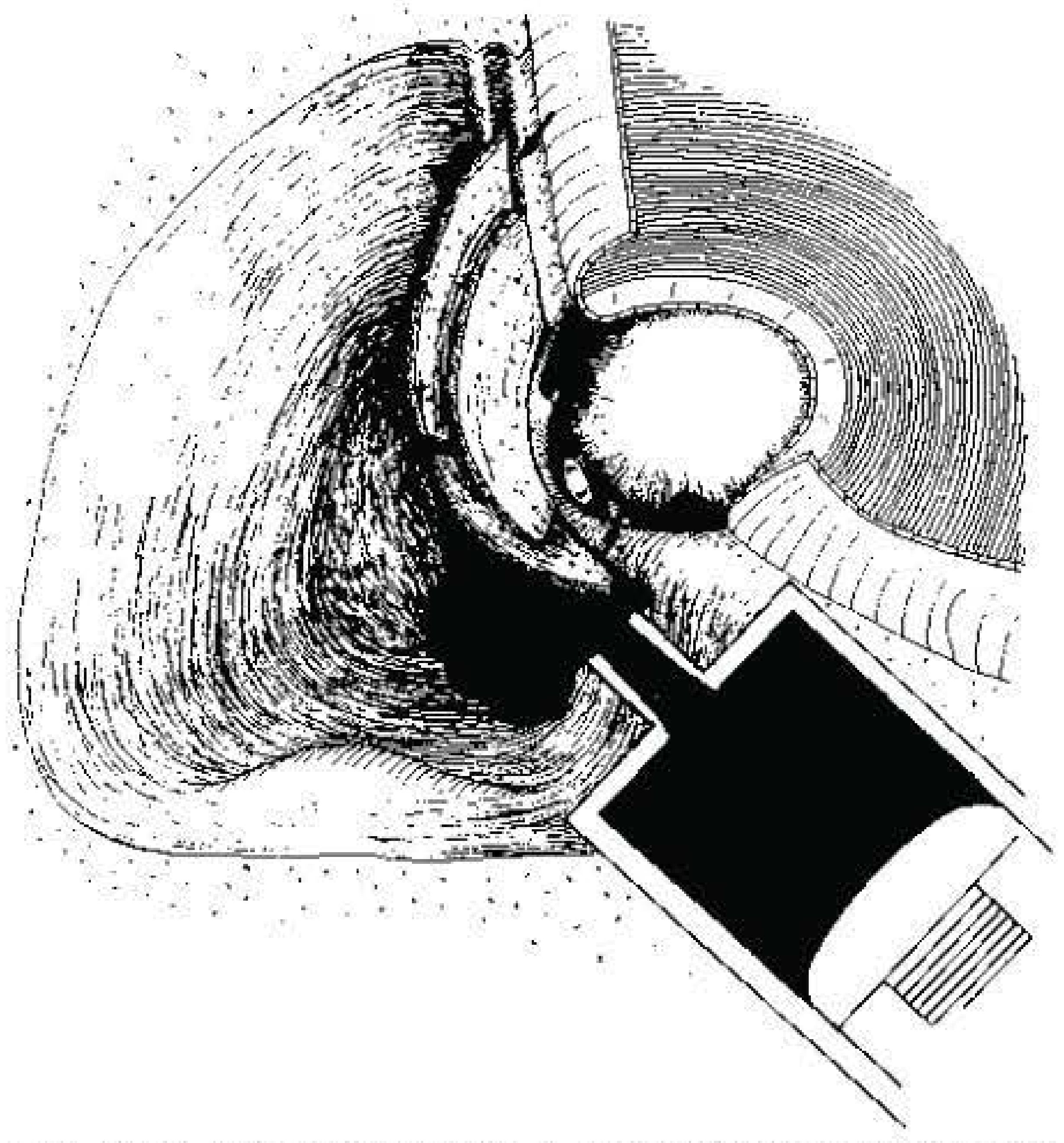


Fig. **1019** The ear canal wall is reconstructed with one to three curved pieces of bone placed in a groove drilled along the zygomatic root and facial ridge (arrows) into the cavity. The pieces of bone are fixed with plaster of Paris introduced into the cavity with a syringe

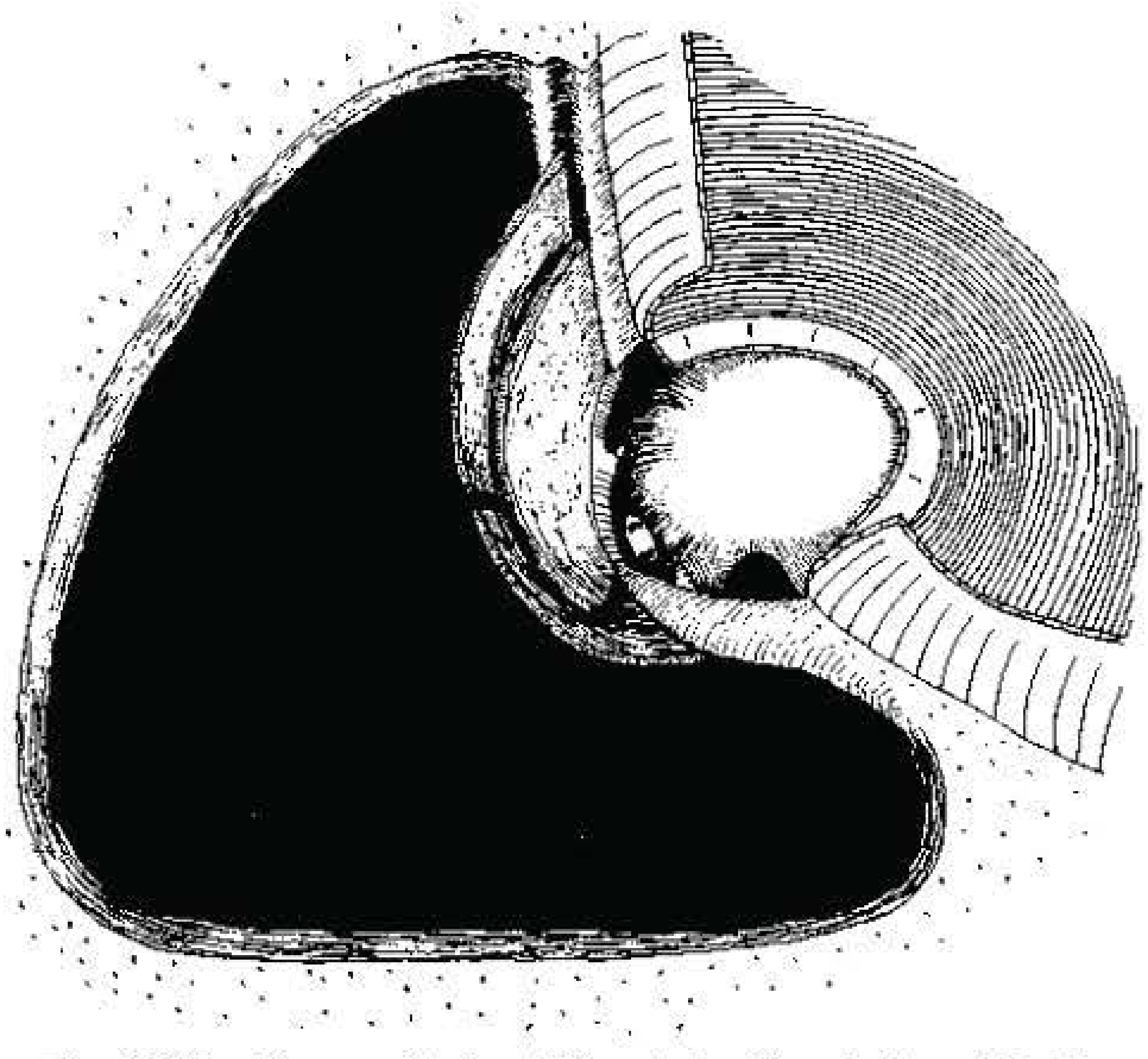


Fig. **1020** The cavity is obliterated with plaster of Paris

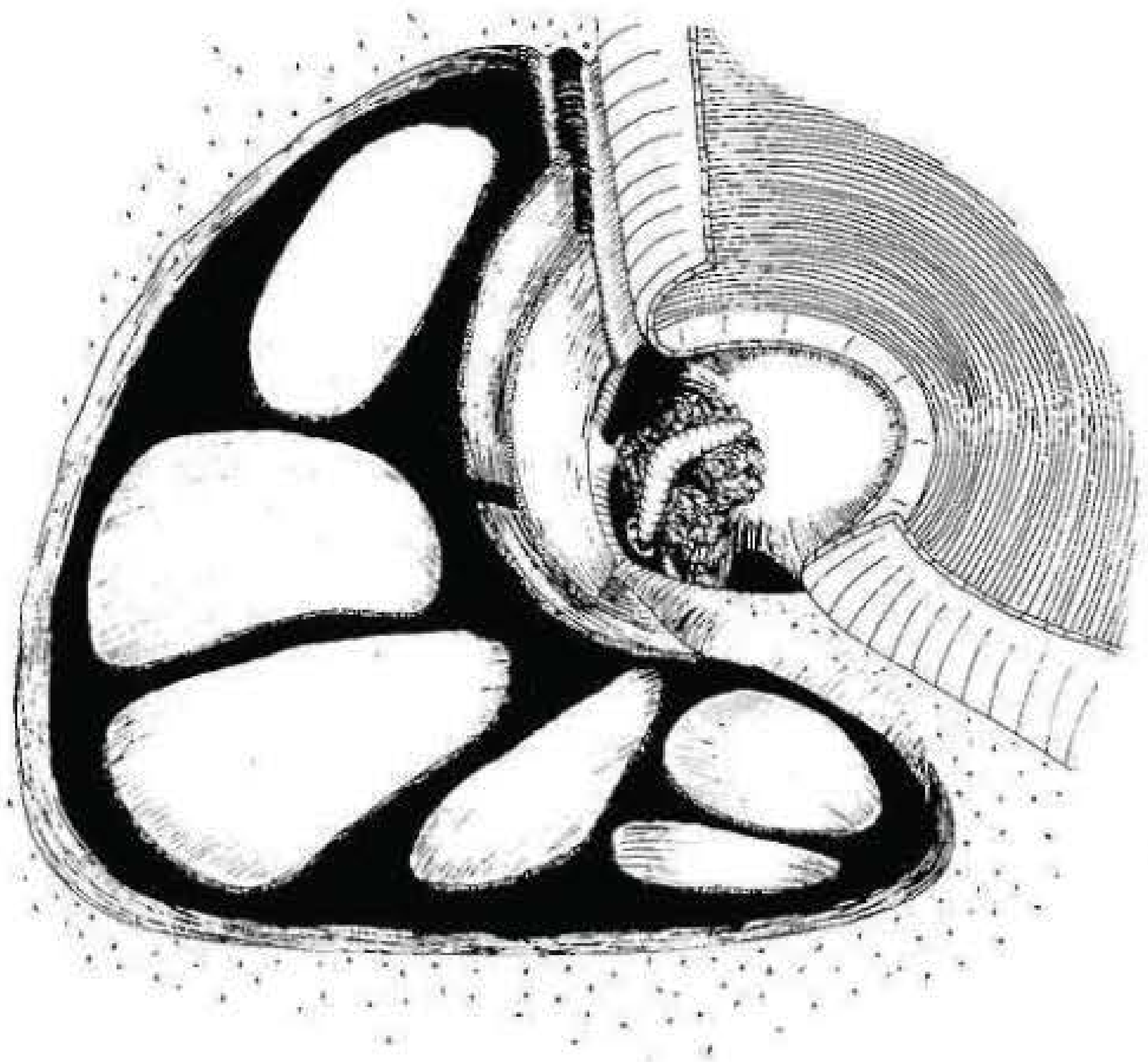


Fig. **1021** Laterally, the plaster of Paris is covered with pieces of bone, and an ossiculoplasty is performed using a columella

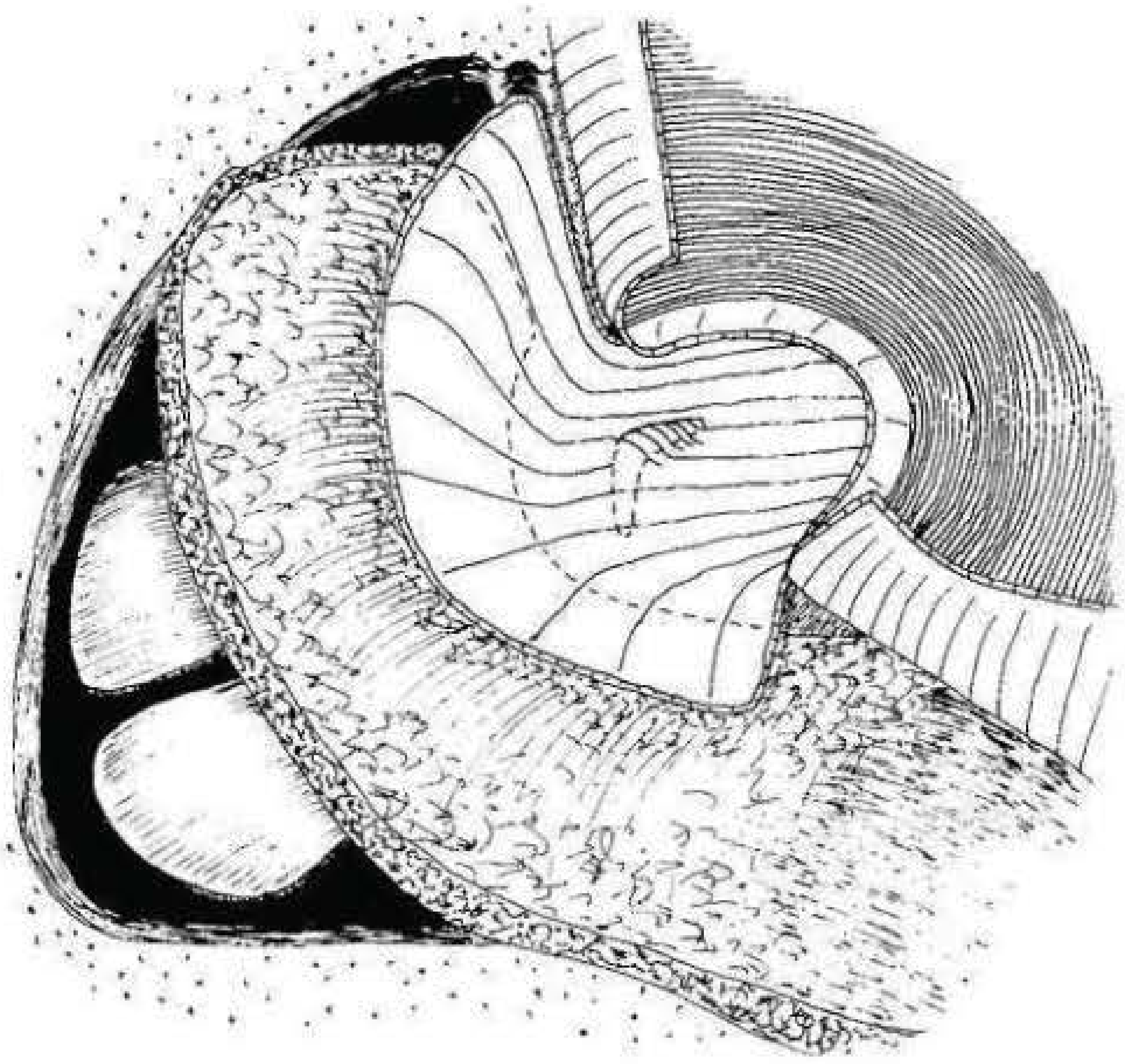


Fig. **1022** The inferiorly-based muscuioperiosteal flap is placed on the meatal side of the reconstructed ear canal wall and on the lateral aspect of the cavity, covering as much of the plaster of Paris and bone at the lateral surface as possible. The fascia covers the total perforation as underlay graft, and the ossiculoplasty extends laterally over the reconstructed ear canal wall and the muscuioperiosteal flap

surgery revealed slight discharge from one ear; the rest were dry. Six patients developed retractions located posterolaterally in the ear canal close to the auricle. In one patient, pieces of bone and plaster of Paris, as well as a protruding bony rim, were removed postoperatively. The five patients with persistent retraction underwent revision surgery during the first two years. It was found that the lateral retractions corresponded to small defects in the most lateral part of the reconstructed posterior bony ear canal wall. The reconstructed bony ear canal wall had grown thicker, except laterally. It was also shown that the plaster of Paris had totally disappeared in three cases which were revised within eight months, and the mastoid cavity was partly obliterated by bony tissue. Thirty-seven percent of patients maintained an ear canal of normal size postoperatively, 40% had a widened ear canal, and 25% developed cavities. Högset and Bredberg consider that filling the mastoid cavity with plaster of Paris solves the problem of fixation of the autogenous bone when reconstructing the ear canal wall. Plaster of Paris stimulates bone formation, but is resorbed and only partially replaced by bone. The problem of progressive and potentially dangerous retraction behind a firmly reconstructed ear canal wall, — described by the authors at follow-up, would therefore appear to be unavoidable.

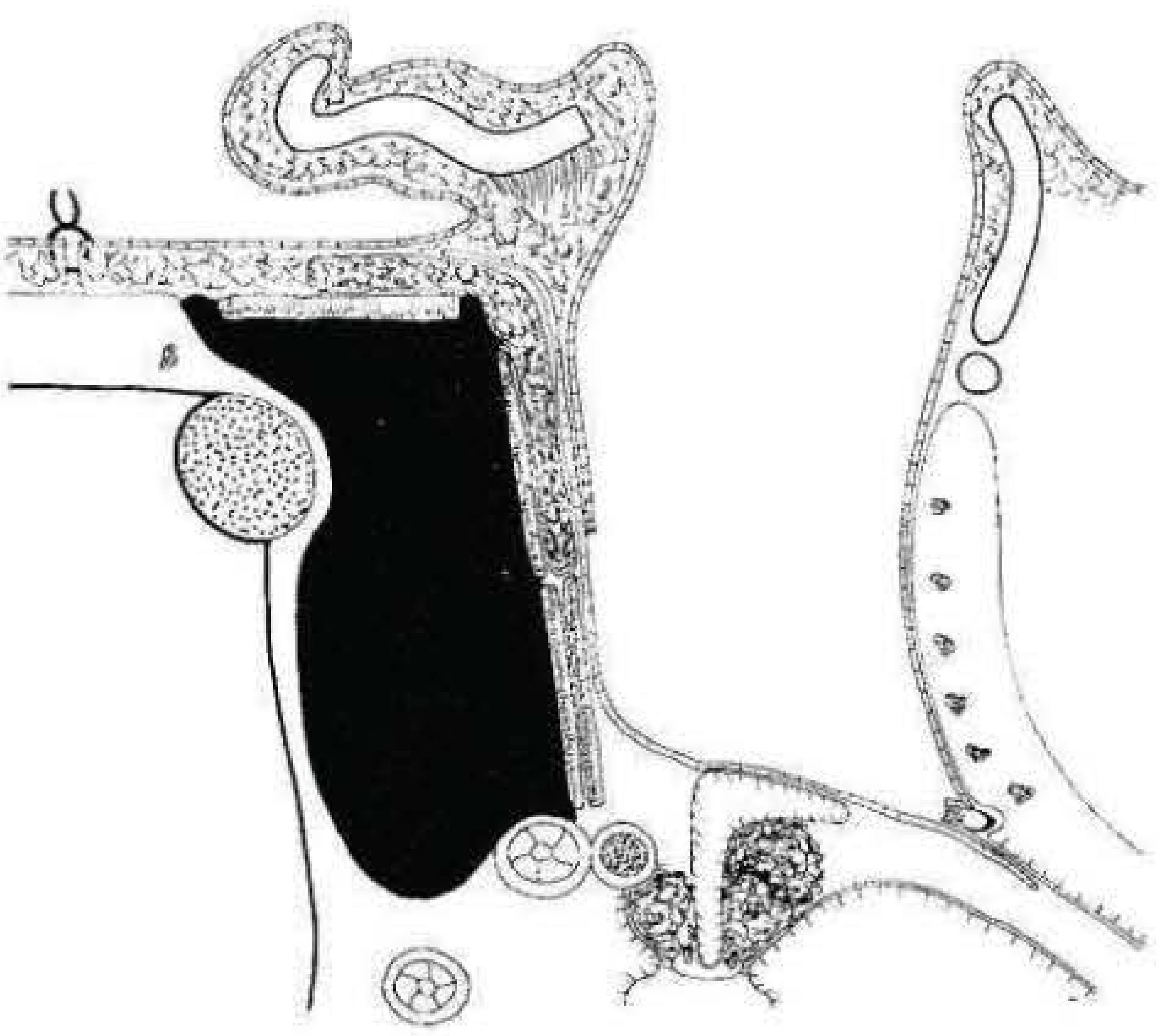


Fig. **1023** Side view of the obliteration technique using plaster of Paris. The ear canal is reconstructed with pieces of bone. The bone also covers the lateral part of the cavity. The muscuioperiosteal flap covers the lateral part of the ear canal wall and the fascia

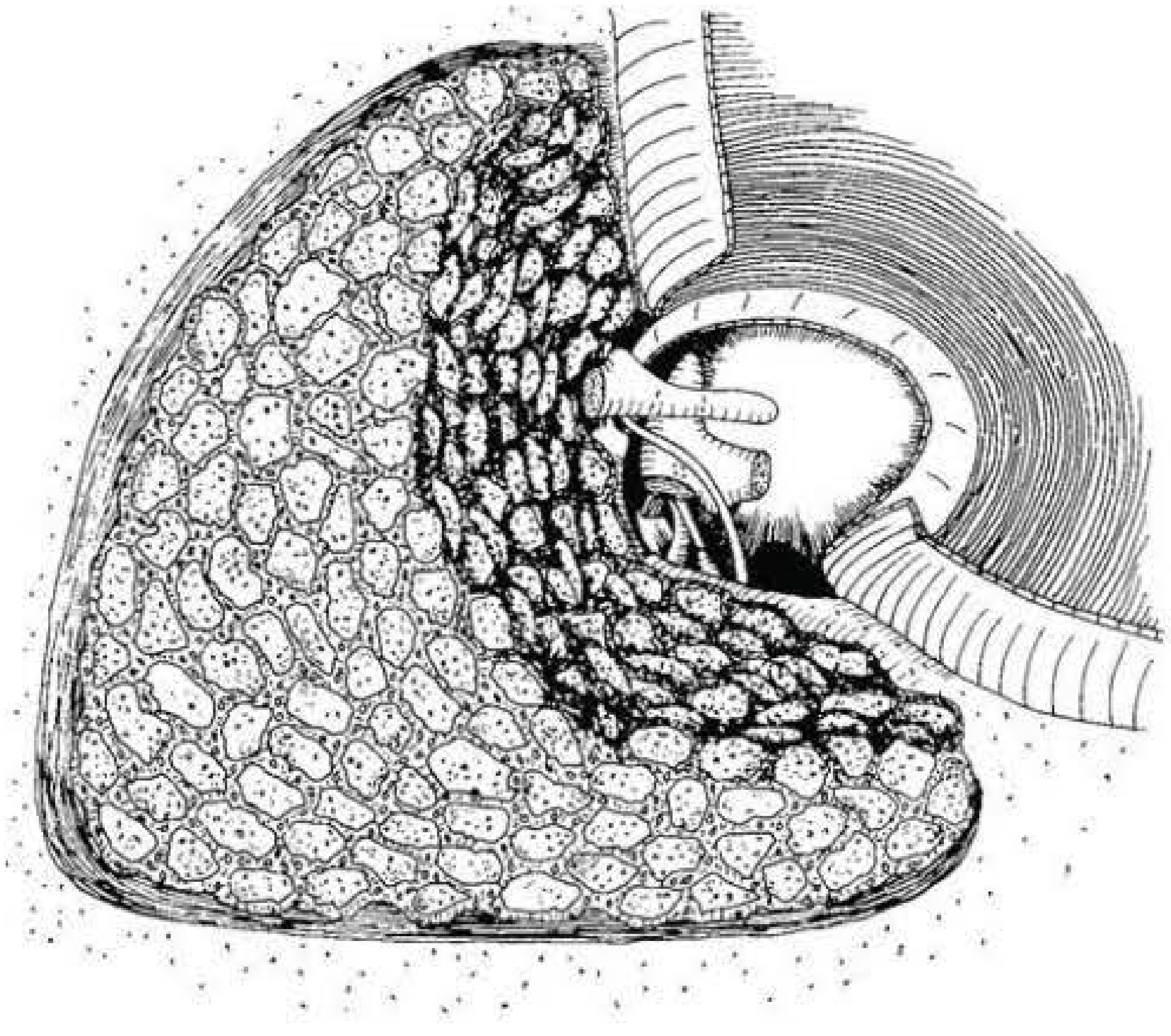


Fig. **1024** **Obliteration of the cavity with Triosite and fibrin glue** (Gersdorff). The cavity is filled with Triosite granules mixed with fibrin glue. The ossiculoplasty is carried out, with interposition of an incus between the stapes and the malleus handle

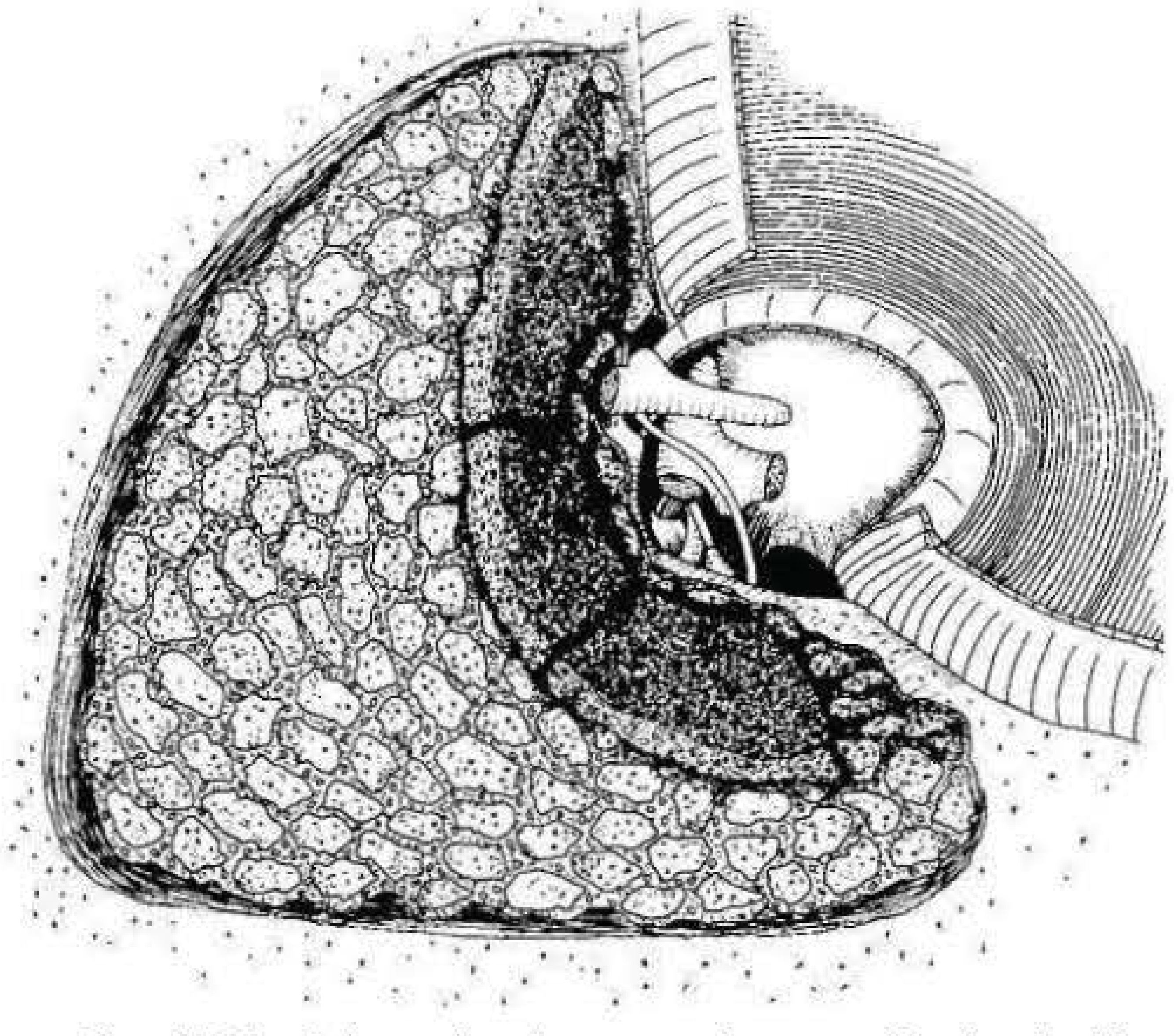


Fig. **1025** Cakes of autogenous bone paté mixed with fibrin glue cover the Triosite granules, creating an ear canal wall

Plasticine

Plasticine is a mixture of pentacalcium hydroxyphosphate nonvitrified powder and fibrin glue (Wullstein et al. 1979). Plasticine is prepared by the surgeon shortly before it is required, in the following way: 1) Hydroxyapatite powder is mixed with one or two drops of antibiotic on a plexiglass plate. 2) It is then mixed with the fibrinogen component of the fibrin glue (Tissucol). 3) The thrombin calcium chloride component of Tissucol is added, and the resulting mass is placed in the cavity in order to obliterate it.

The mass can be adapted into the required shape. For example, it can be molded to form a new posterior ear canal wall or to cover defects of the middle or posterior fossa bony plates.

Plasticine can be mixed with autogenous bone paté. The Wullsteins use plasticine to cover an osteoplastic epitympanotomy (Wullstein and Wullstein 1990). Plasticine is apparently not used by any other surgeons.

Triosite

Triosite, porous granules (Xomed, Inc.) are a mixture of tricalcium phosphate (40%) and hydroxyapatite (60%). Hydroxyapatite is a biocompatible substance that is not initially bioabsorbable, while tricalcium phosphate is biodegradable and bioabsorbable, and its breakdown products are used by the body for the formation of new bone. The diameter of the granules is 0.5–1.0 mm, and the diameter of the pores is 400–600 µm.

In order to obliterate a canal wall–down mastoidectomy, Gersdorff and Robillard (1987) used Triosite ceramic granules incorporated with fibrin glue. This compound is malleable, and can be used to fill the entire cavity. Fibrin glue binds the granules together, and attaches them to the cavity wall (Fig. **1024**). The granules are covered by a sheet of bone paté and fibrin glue mixture (Fig. **1025**), which is itself covered by a large temporalis fascia graft, if possible surrounding it (Fig. **1026).**

As it was recognized that the layer of bone paté and fibrin glue does not cover the Triosite granule adequately, this method of covering was abandoned, and has been replaced by the use of a large Palva flap (Fig. **1027**) (Gersdorff and Garin 1992).

Using Triosite and fibrin glue as an obliteration material, Olaizola et al. (1989) attempted to ventilate the antrum and attic and obliterate only the lateral part of the cavity. A mold of the space occupied by the antrum and the attic is made by filling the antrum with a silver chain (Fig. **1028**). The

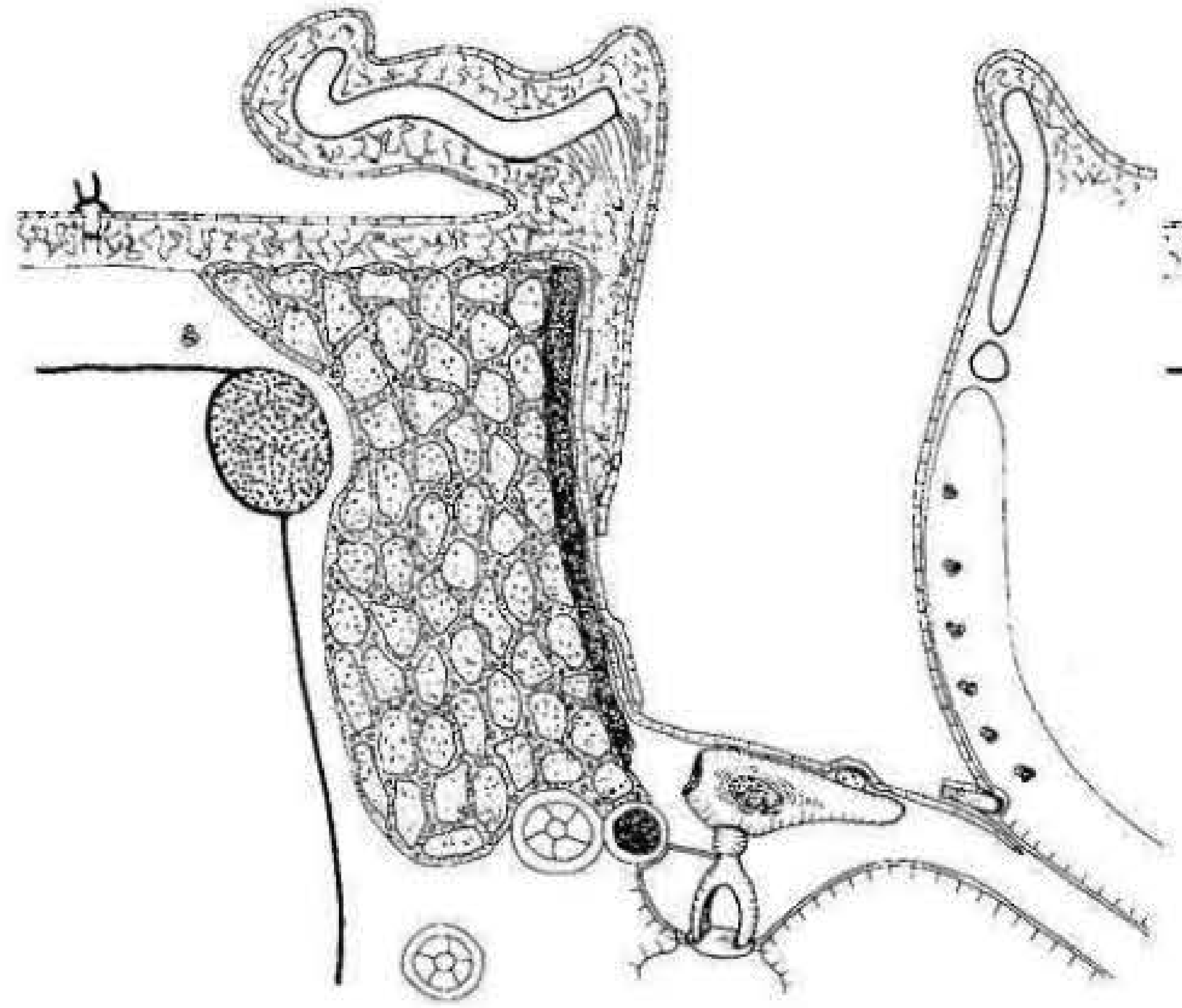


Fig. **1026** Side view of obliteration with Triosite. A slice of bone paté with fibrin glue covers the Triosite. A piece of fascia, as an underlay graft, covers the perforation and the interposed incus. It continues over the bone paté slice. Another large piece of fascia covers the lateral part of the bone paté slice

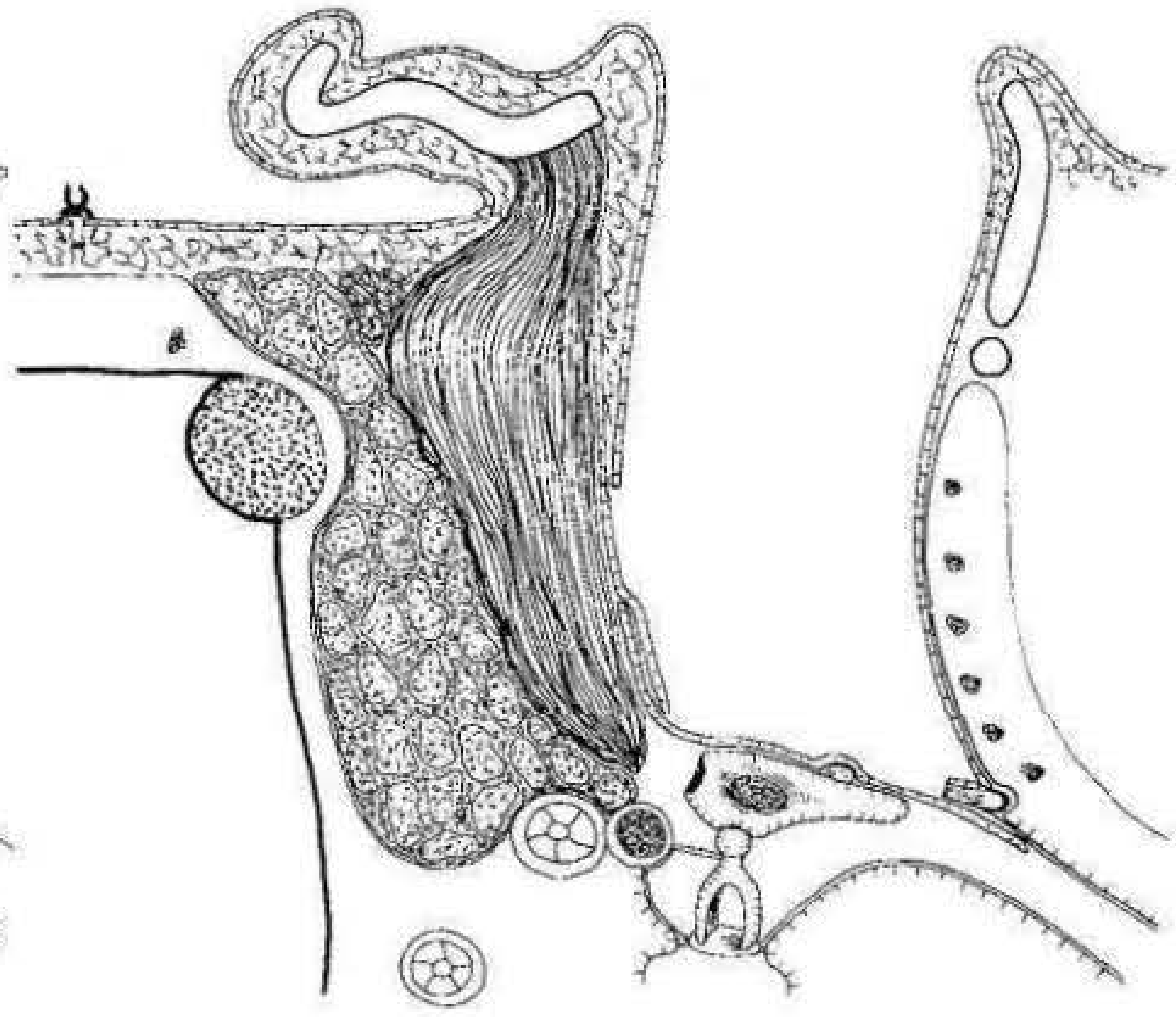


Fig. **1027** **Revision of the Triosite obliteration technique** (Gersdorff and Garin), applying reconstruction of the ear canal wall with a large Palva flap. The Triosite granules are mainly obliterating the posterior aspect of the cavity

silver chain is later removed. Prior to obliteration, the silver chain is covered by a Silastic sheet to prevent the Triosite mixing with the chain (Fig. **1029**).

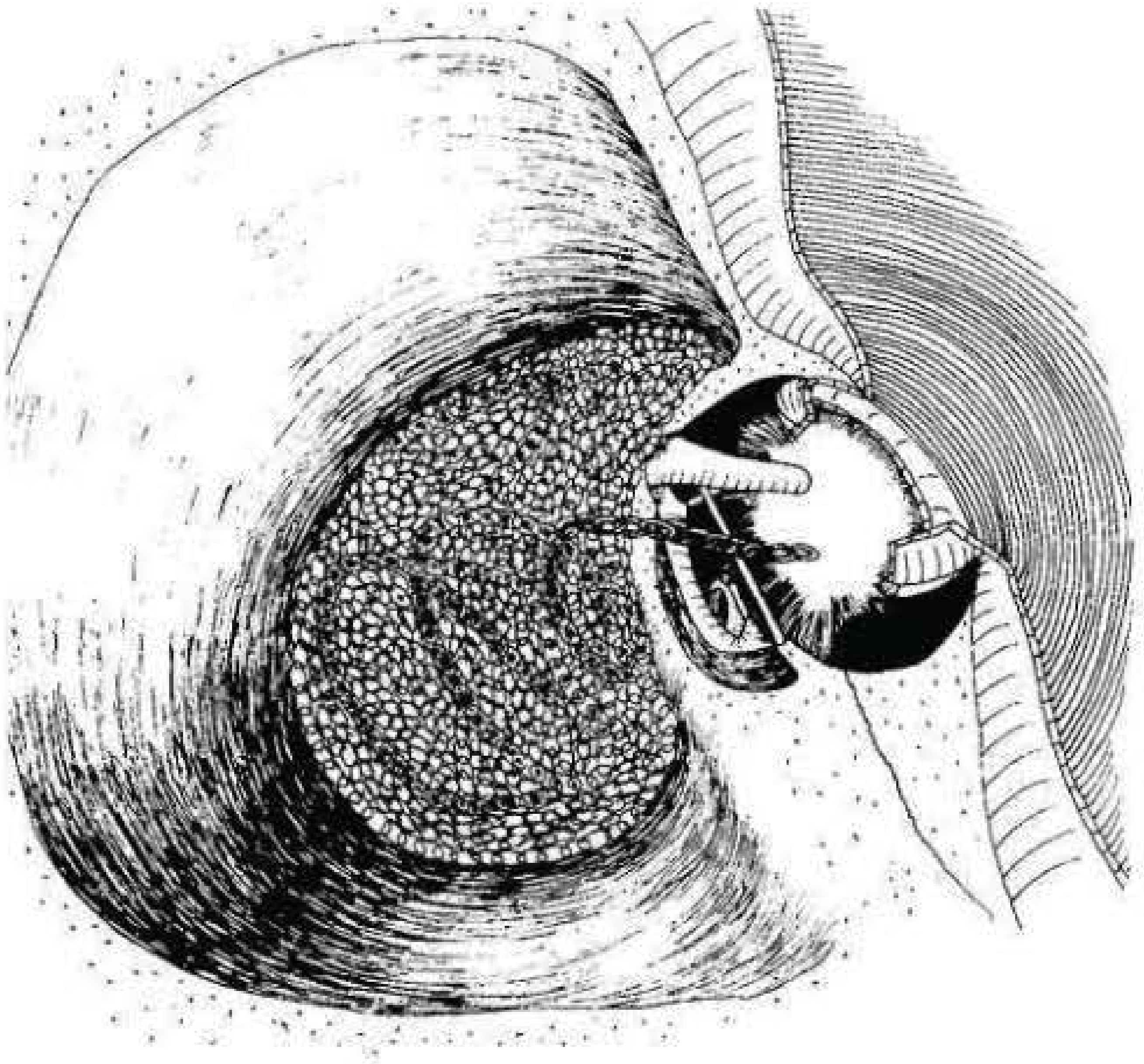


Fig. **1028** **Obliteration of the lateral part of cavity with Triosite and ventilation of the antrum** (Olaizola) After a canal wall–down mastoidectomy, a silver chain fills the medial part of the cavity, including the antrum and the attic. One end of the chain is visible on the promontory

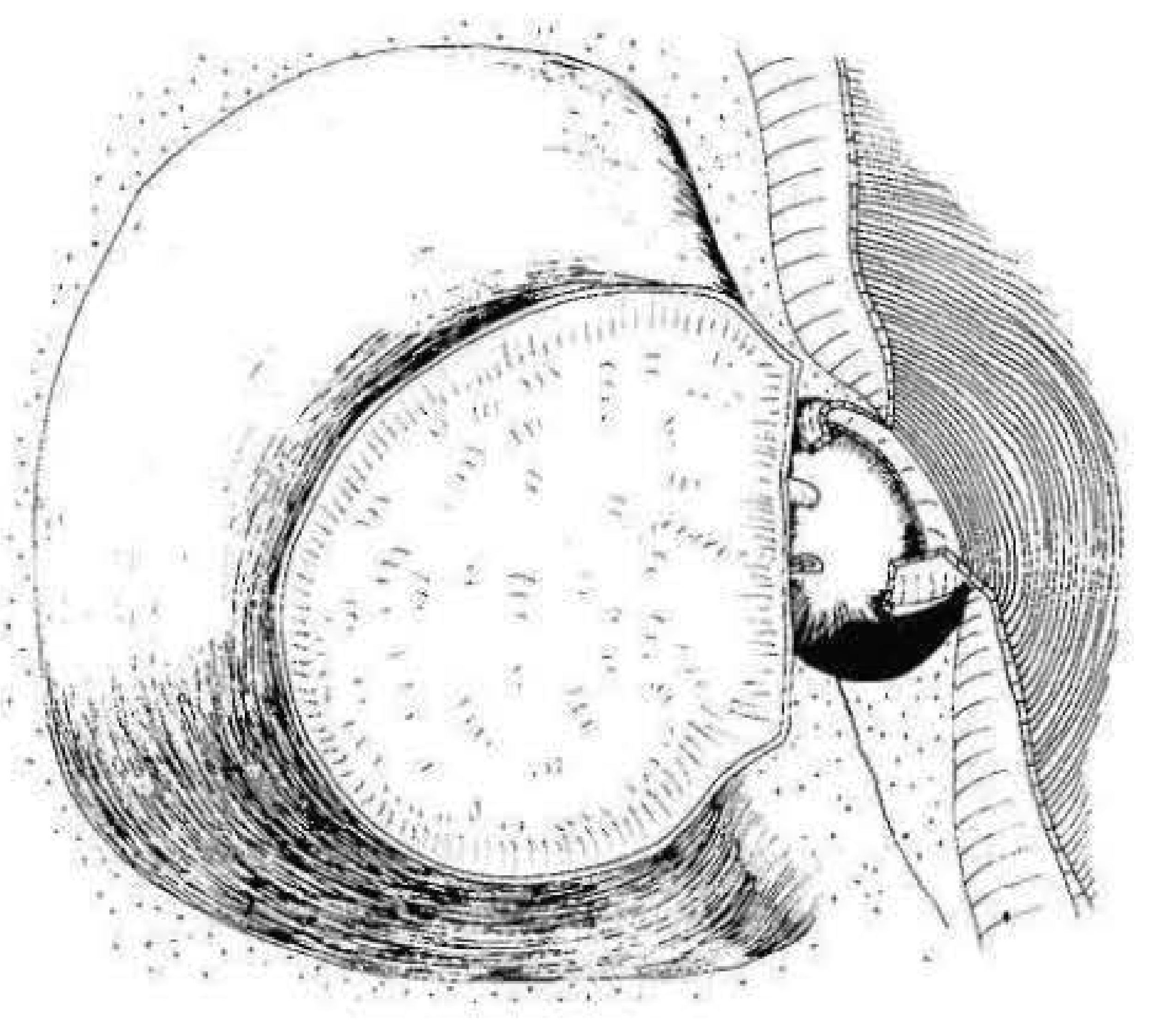


Fig. **1029** **A Silastic sheet covers the silver chain at the level of Körner's septum.** Lateral to the Silastic sheet, the cavity will be obliterated using Triosite and fibrin glue

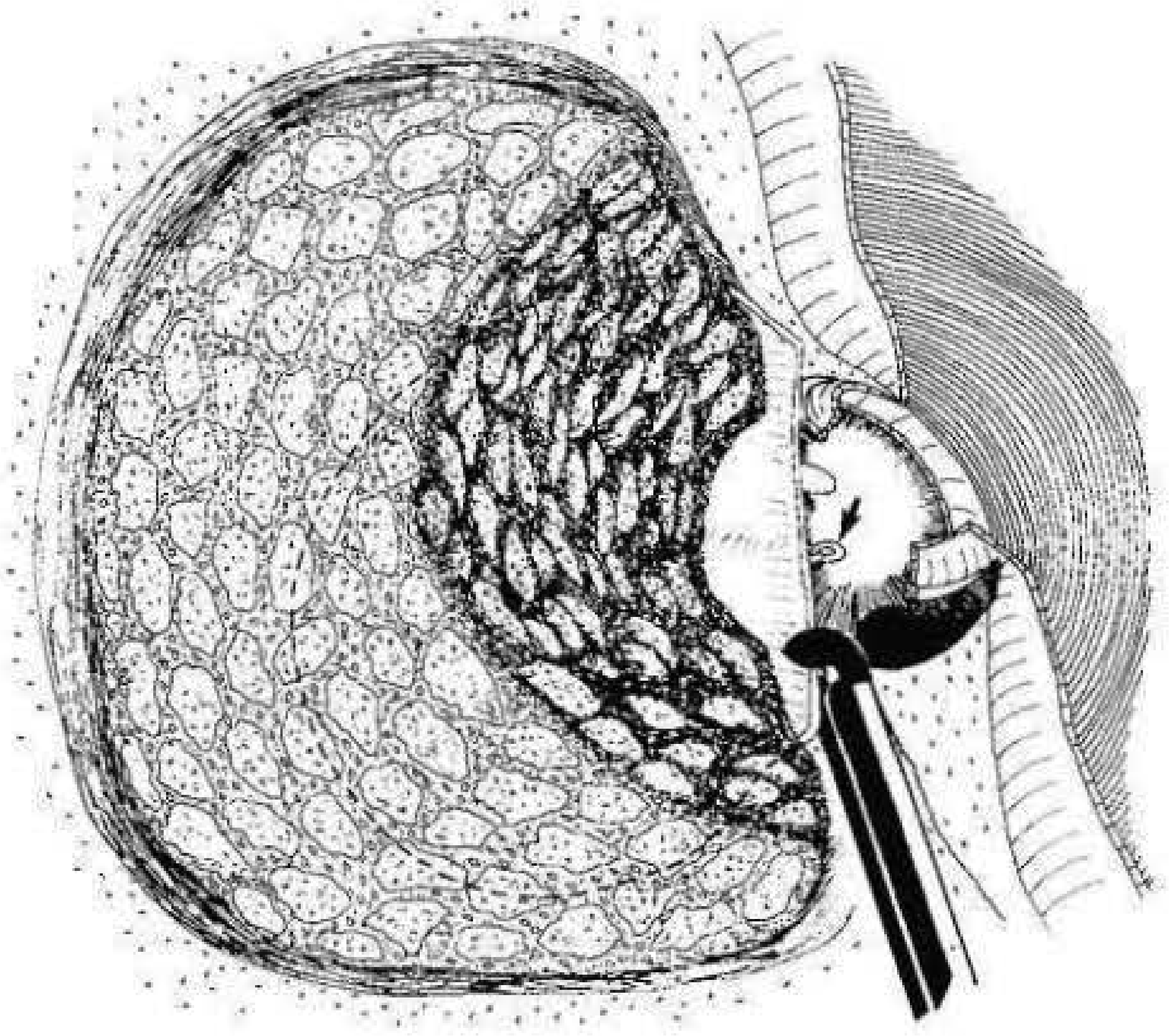


Fig. **1030** The lateral part of the cavity is obliterated with Triosite granules mixed with fibrin glue. After the granules are solidly fixed and hardened, the Silastic sheet is removed, followed by the silver chain (arrow)

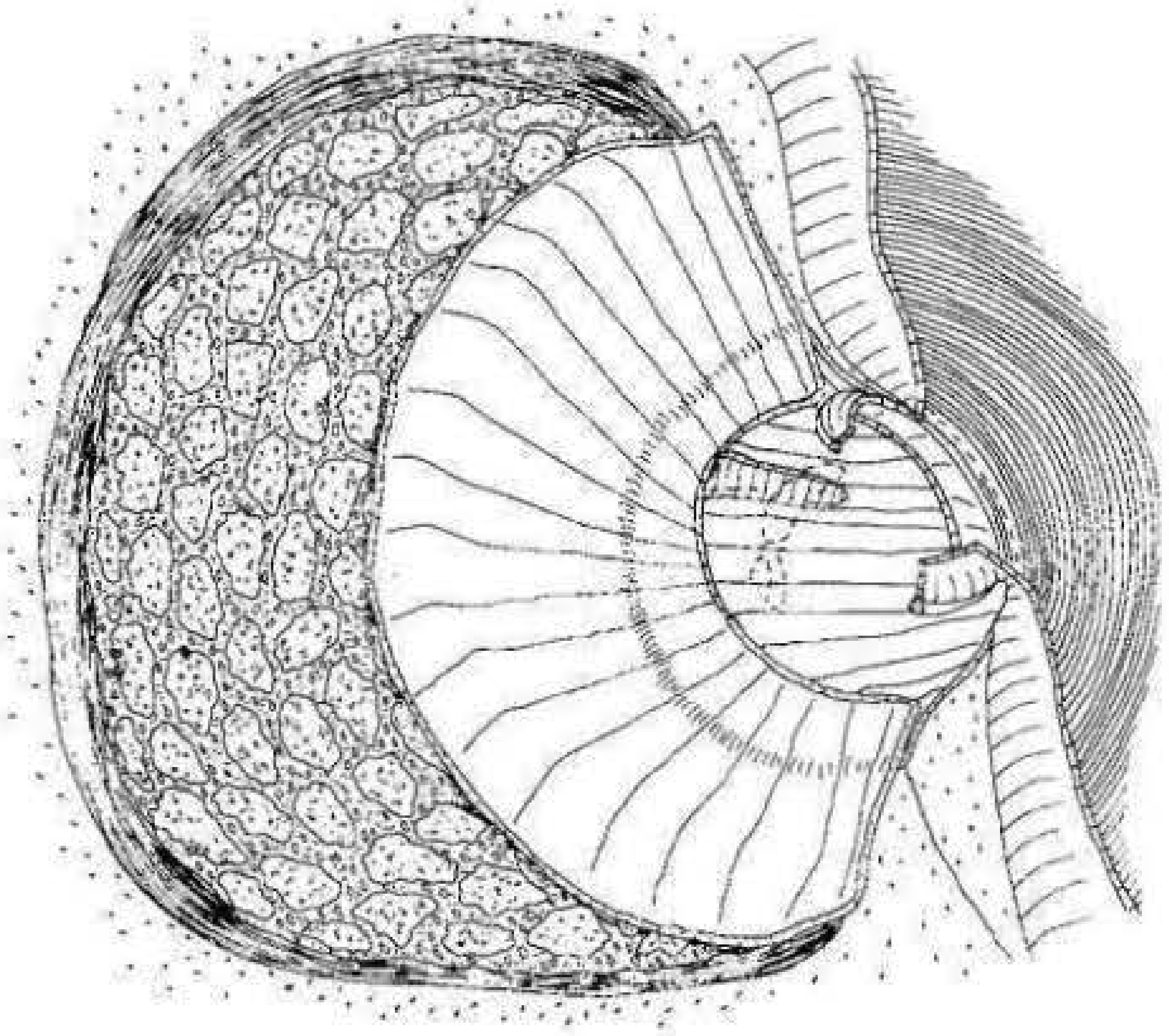


Fig. **1031** The total perforation is reconstructed with the fascia as an underlay graft. Ossiculoplasty is performed with a piece of cortical bone. The fascia covers the Triosite granules medially. Another large piece of fascia covers the ear canal wall region, and partially covers the lateral part of the cavity

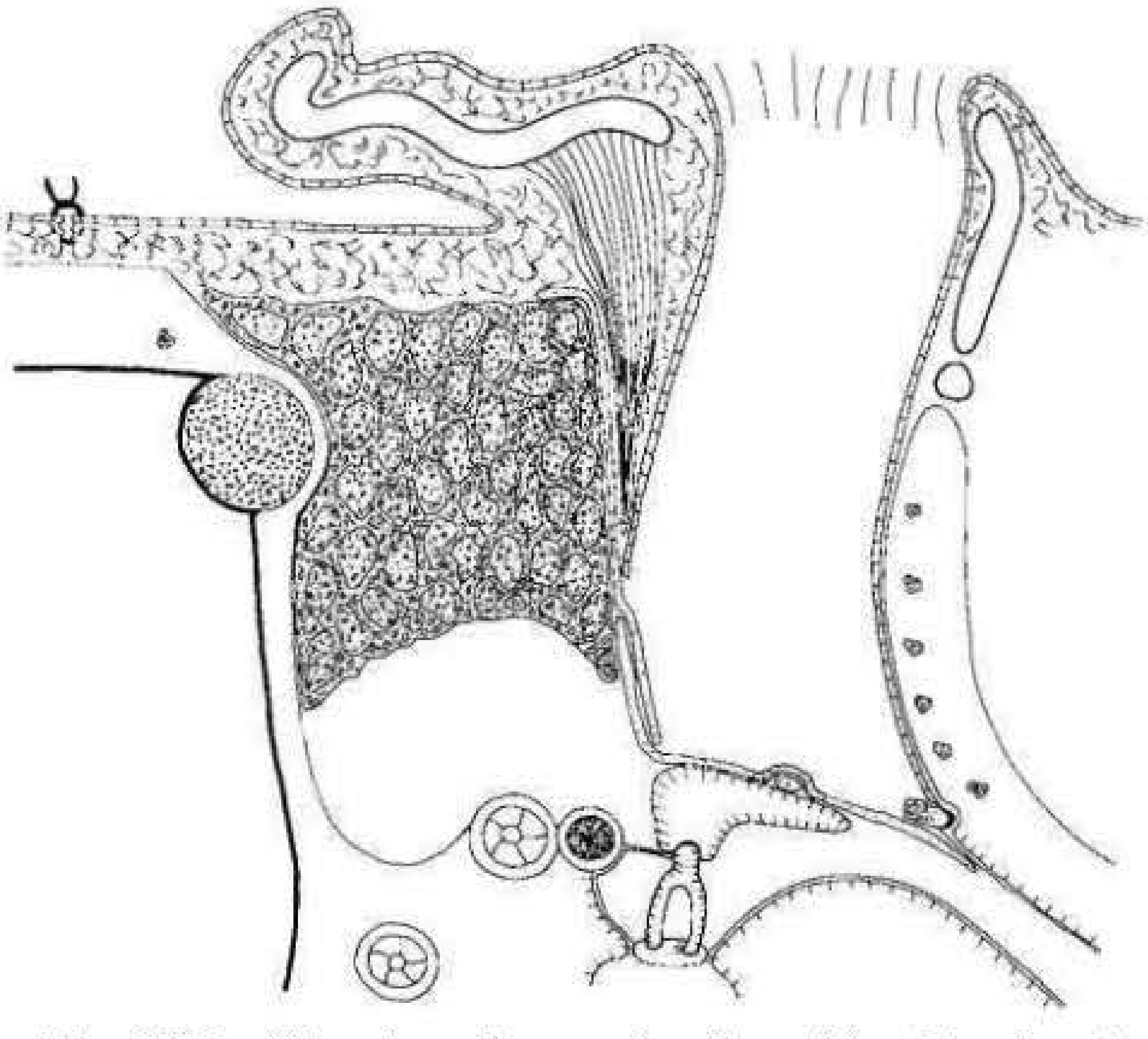


Fig. **1032** Side view of reconstruction of the lateral part of the cavity with Triosite and ventilation of the antrum Fascia, as an underlay graft, covers the perforation and the ossiculoplasty. It covers the Triosite granules medially. Another large piece of the fascia and a Palva flap cover the lateral part of the ear canal wall. The antrum is ventilated, and communicates widely with the tympanic cavity

The Triosite, mixed with fibrin glue, is used to obliterate the lateral part of the cavity (Fig. **1030**). The silver chain and the Silastic sheet are removed once the triosite has hardened. After reconstructing the tympanic cavity and covering the ear canal wall with both fascia (Fig. **1031**) and the musculoperiosteal flap, the medial part of the cavity, including the antrum and attic, is intended to be ventilated by wide comunication with the tympanic cavity, whilst only the lateral part is obliterated (Fig. **1032**).

Hydroxyapatite

Porous granules of hydroxyapatite have been increasingly used in the obliteration of mastoid cavities. Several principles of obliteration have been applied: 1) Using the hydroxyapatite granules behind a preserved bony ear canal wall in a second-stage operation, after earlier intact canal wall mastoidectomy (Fig. **384**) (Yanagihara and Hinohira 1989, Yanagihara et al. 1993). 2) Hydroxyapatite granules mixed with fibrin glue used in similar way as described in obliteration with Triosite (Fig. **1024**). 3) Using hydroxyapatite granules covered meatally by a musculoperiosteal flap (Yanagihara and Hinohira 1989), similar to Figure **1030.** 4) Using hydroxyapatite behind bone chips (Takahashi and Nakano 1990).

Nakano (1993) performs mastoidectomy leaving a high facial ridge, obliterates the cavity with hydrodyapatite granules, and reconstructs the ear canal wall with slices of cortical bone (Takahashi and Nakano 1990).

After canal wall–down mastoidectomy with preservation of a high facial ridge, very thin slices of cortical bone are harvested using a broad flat chisel. The posterior canal wall is reconstructed using bone slices, mainly to prevent exposure of the hydroxyapatite granules through the ear canal. First, a large, curved bone slice is placed on the medial wall of the attic, completely sealing the attic off from the tympanic cavity. Several small slices are placed behind this large slice for further closure of any gap, and behind these yet more thin slices are placed (Fig. **1033**), gradually reconstructing the ear canal wall. The attic wall is reconstructed more superiorly than its original position, giving a larger drum. The spaces between the bone slices are filled with fibrin glue, fixing the bone slices into a solid wall (Fig. **1034**). Behind the ear canal, the empty cavity is packed with hydroxyapatite granules as uniformly as possible, avoiding the creation of large empty spaces, and any such spaces are filled with fibrin glue

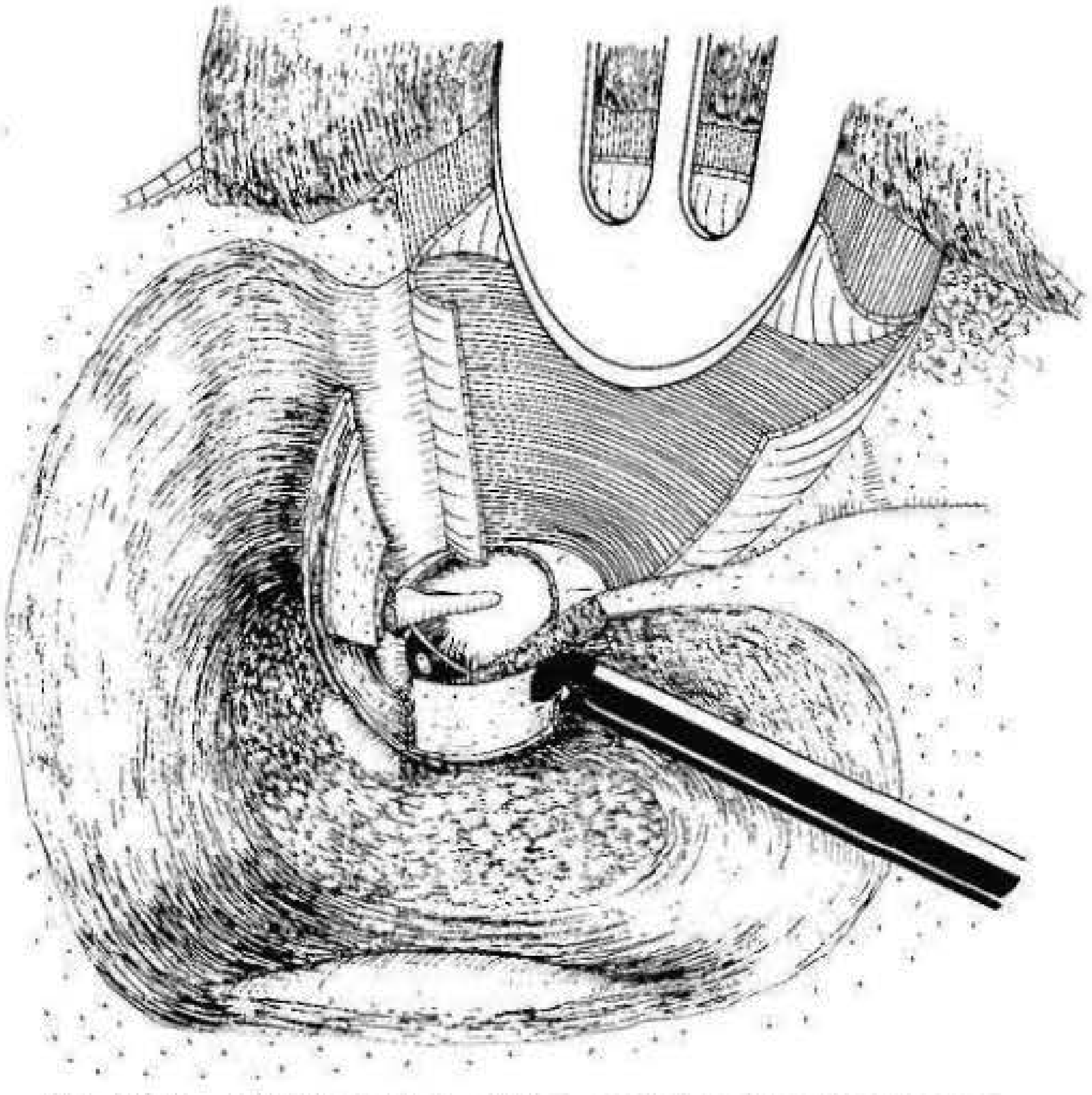


Fig. **1033** **Obliteration of the cavity using hydroxyapatite granules and reconstruction of the ear canal with bone slices** (Nakano). Slices of bone are placed on the medial wall of the attic, completely reconstructing the ear canal wall

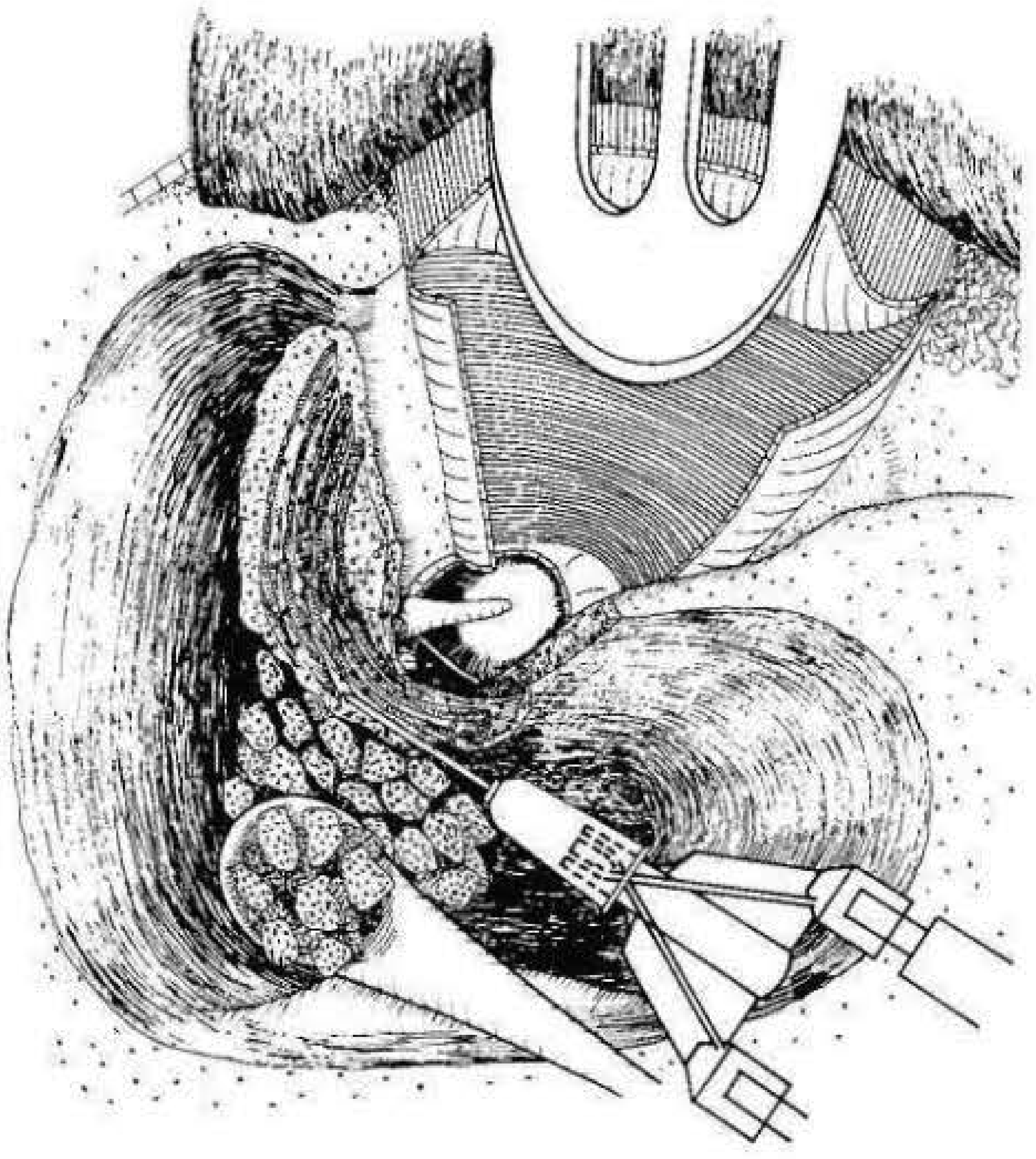


Fig. **1034** Several slices reconstruct the ear canal wall. They are fixed with fibrin glue placed around and between them. Granules of hydroxyapatite are placed behind the reconstructed ear canal wall

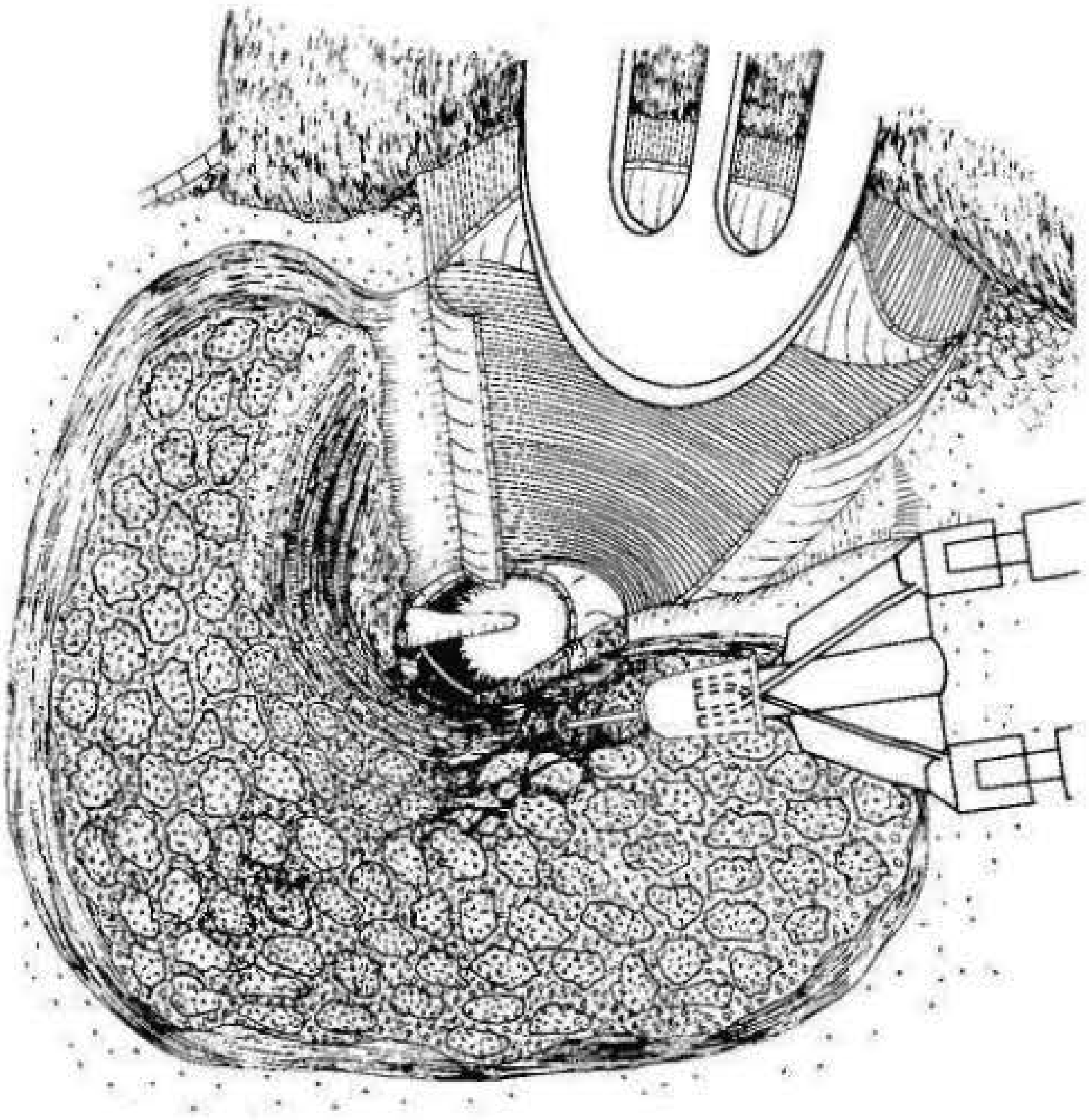


Fig. **1035** The entire cavity is obliterated with hydroxyapatite granules, and fibrin glue is placed between the granules

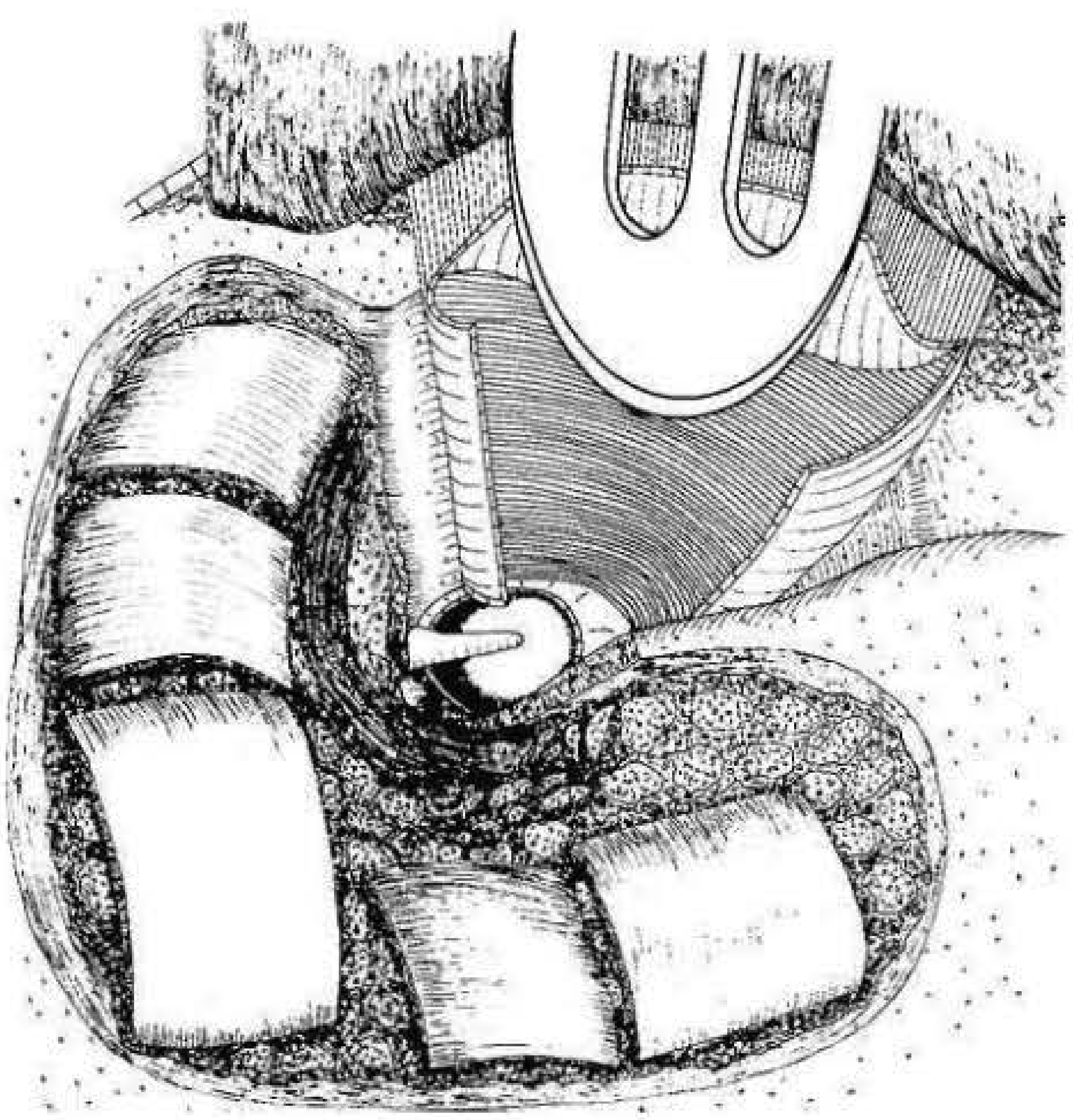


Fig. **1036** Slices of bone cover the lateral wall of the cavity, and fibrin glue fixates and covers the bone slices

(Fig. **1035**). The lateral wall of the cavity is covered with several slices of bone, which are fixed in position with fibrin glue (Fig. **1036**). After ossiculoplasty, fascia is used as an underlay graft to cover the perforation as well as the reconstructed ear canal wall (Fig. **1037**). A Palva flap is used, and the lateral skin flaps are replaced (Fig. **1038**).

The principle behind this method is based on a high facial ridge mastoidectomy and the extremely thin slices of bone used for the ear canal wall reconstruction. During the canal wall–down mastoidectomy, as much of the posterior ear canal wall is preserved as possible (Figs. **1039**, **1040**) in order to facilitate reconstruction with bone slices.

Late results 1–4 years after surgery of 48 years, showed a retraction rate of 19%, exposure of ceramic in 4%, and infection 8%.

Experiments on the implantation of hydroxyapatite granules into guinea-pig bulla showed that the area between the hydroxyapatite particles becomes occupied by compact bone. The newly formed bone has a laminar structure, particularly at the periphery of the hydroxyapatite (Takahashi and Nakano 1992).

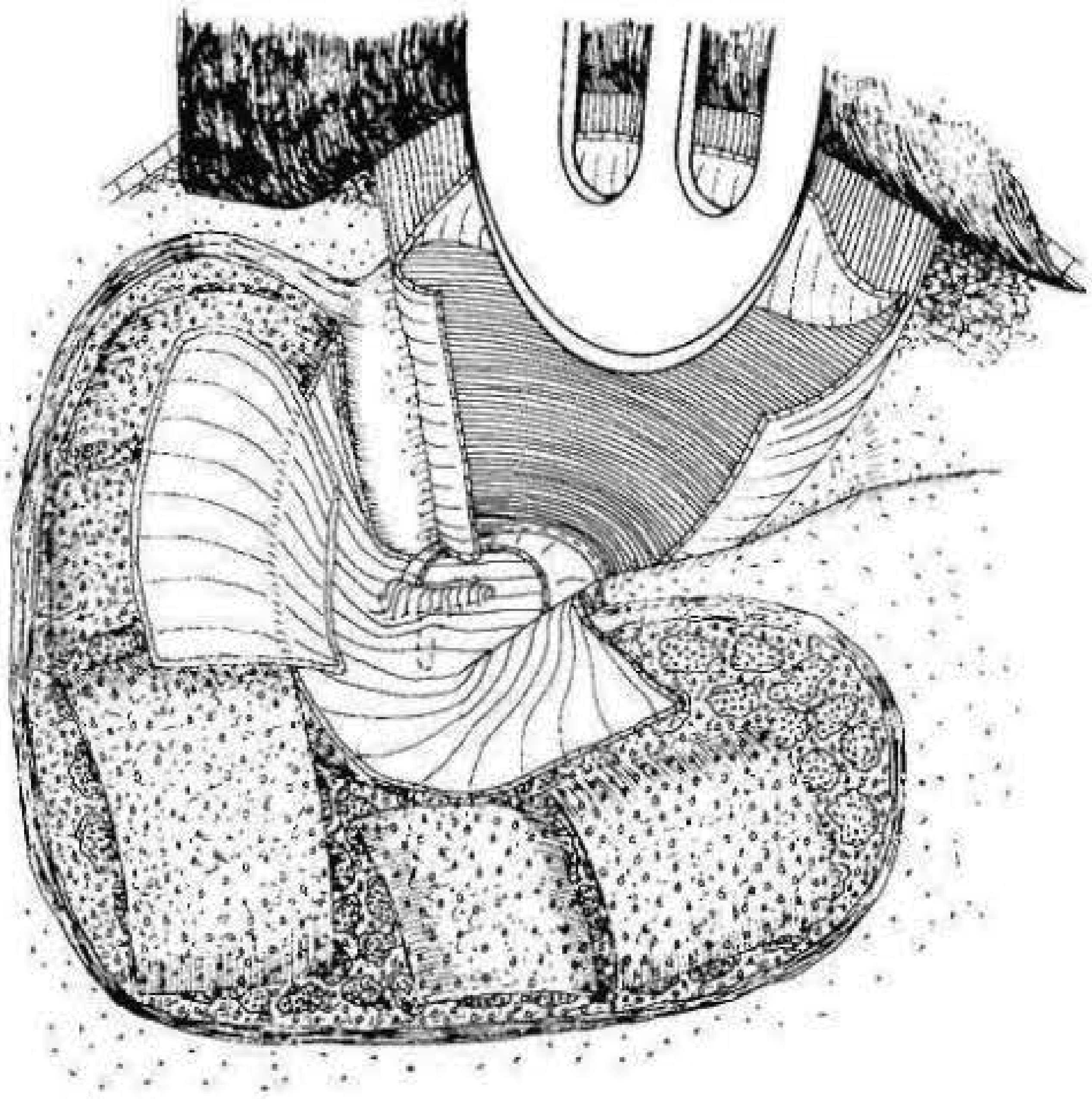


Fig. **1037** Fascia covers the total perforation and the ossiculoplasty. It continues over the reconstructed ear canal wall. Laterally, another piece of fascia covers the meatal wall. Finally, the Palva flap is to be placed in position

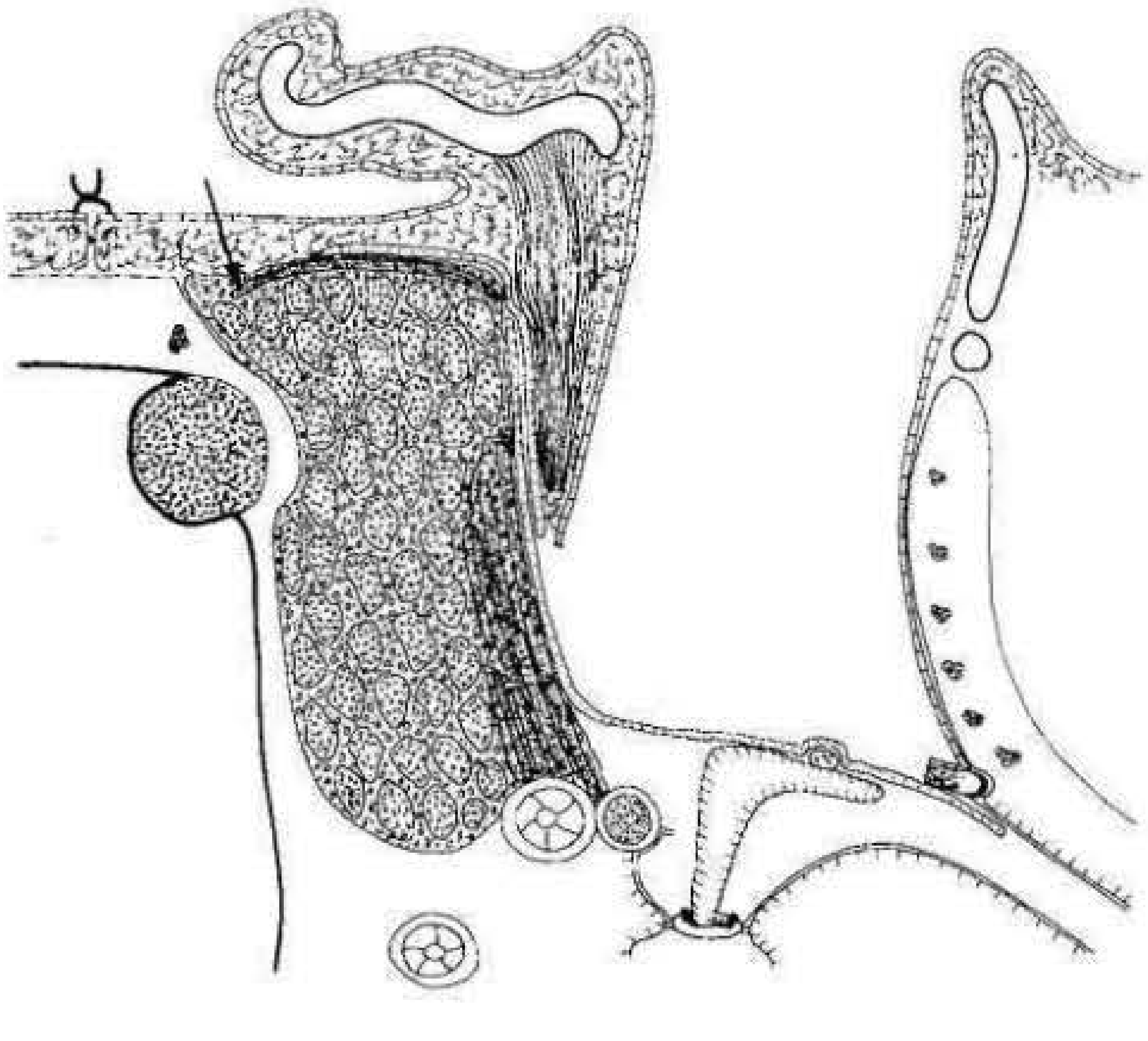


Fig. **1038** Side view of reconstruction **of** the ear canal with bone slices and obliteration of the cavity with hydroxyapatite granules. Medially, the ear canal is solidly reconstructed with bone slices supported with fibrin glue, and laterally with a Palva flap. Fascia covers the meatal side of the ear canal wall. Laterally, bone slices (arrow) and fibrin glue cover the lateral cavity wall. The bone slices are further covered with a piece of fascia

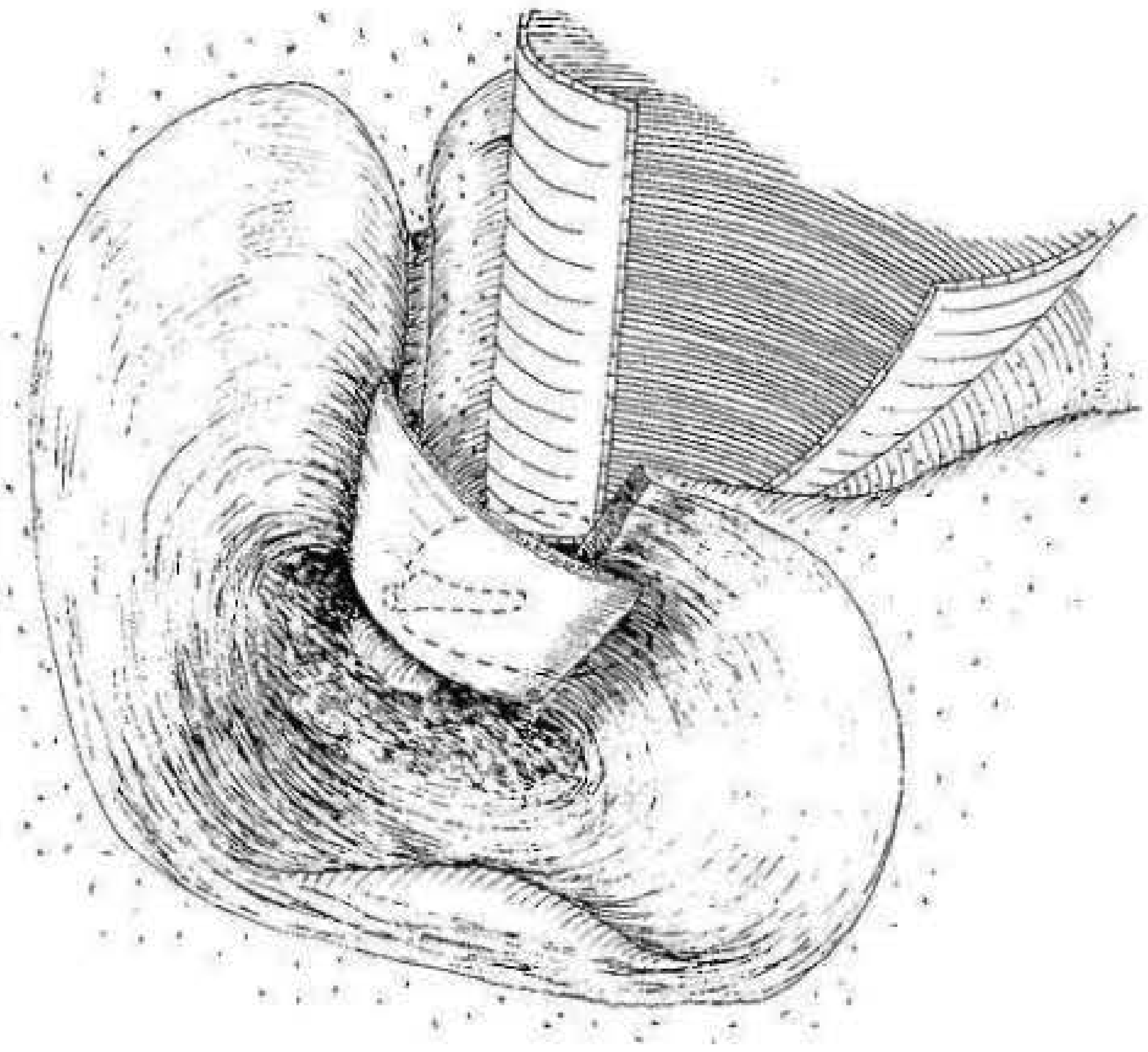


Fig. **1039** **Preserved parts of the bony ear canal wall in a canal wall–down mastoidectomy** (Nakano) The ear canal wall is medially reconstructed with a large slice of bone

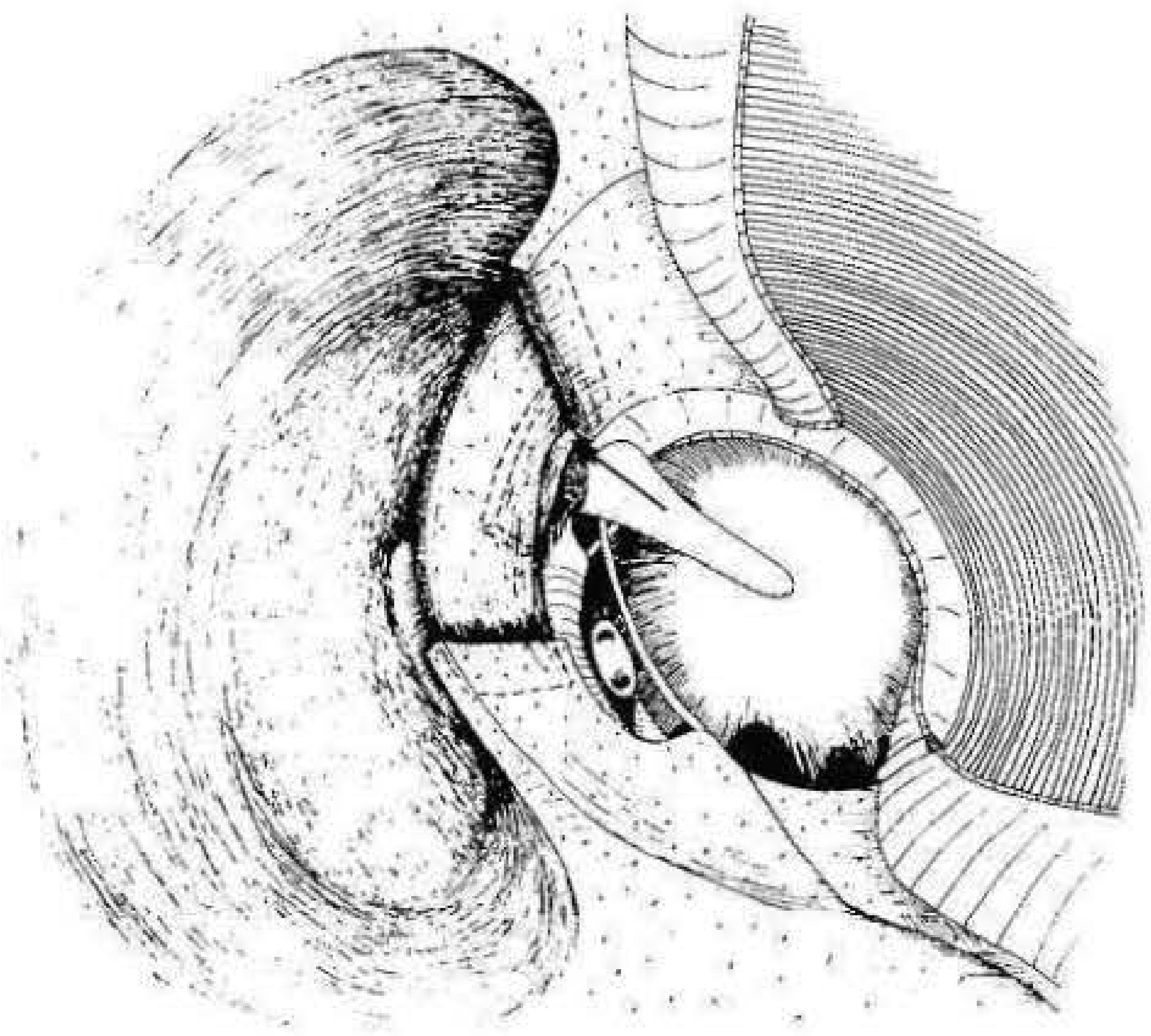


Fig. **1040** The ear canal wall is further reconstructed, and the connection between the tympanic cavity and the mastoid cavity is tightly closed with bone (arrow)

Glass Ionomer Cement

Glass ionomer cement, used for bone reconstruction, is obtained by the reaction of a glass powder consisting of calcium aluminosilicate glass with a polycarboxylic acid. A preformed granular material, IONOS granulate, is used for obliteration of a cavity (Geyer and Helms 1992). The less accessible recesses and niches, such as the sinodural angle or the mastoid tip of a small to middle-sized cavity, are filled with glass ionomer cement granulate. A retroauricularly-based musculoperiosteal flap is rotated to cover the granulate, with care being taken to cover all the material. After this partial obliteration, a small selfcleaning cavity was thus created in a series of 44 patients. Epithelialization of the mastoid cavity was found to be complete after three months, even when the pedicled musculoperiosteal flap had initially provided incomplete coverage of the granulate. Histology revealed nonreactive intergration of the granulate. Fibrous tissue had grown into the mastoid cavity and enveloped the granules from the adjacent soft tissue of the Palva flap. There was no evidence of inflammation or degradation of the material. Late results are, however, lacking, and no other surgeons have apparently used this granulate to obliterate a cavity.

22 Obliteration with a Fat Graft

Fat is rarely used as an obliteration material in middle ear surgery, whereas in translabyrinthine acoustic neuroma surgery, fat is the only material used to obliterate the huge translabyrinthine cavity and prevent cerebrospinal fluid leakage.

In extensive petromastoid surgery for carcinoma of the middle ear, fat grafting has been used since the 1940s (Penha 1951, Piquet et al. 1958), and in translabyrinthine acoustic neuroma surgery, it has been used since the early 1960s by House (House and Luetje 1979).

In middle ear surgery, van Deinse proposed a method of extended antrotomy for inspection of the tympanic cavity, whilst partly preserving the posterior ear canal wall, as well as the bridge. He suggested filling the retroauricular cavity with abdominal fat (van Deinse and van den Borg 1958, Kuhweide and van Deinse 1960). After radical mastoid surgery, Kadariu (1960) used fat for obliteration of the cavity. Ringeberg and Fornato (1962) used fat for cavity obliteration in specific cases with an intakt posterior bony ear canal wall or intact ear canal skin. In myringoplasty, fat is sometimes used to close small perforations (Vol. 1, pp. 117–18).

The author has used abdominal fat in more than 650 patients after translabyrinthine removal of acoustic neuromas (Tos and Thomsen 1991) and other skull base surgery procedures, but only very occasionally for obliteration of a cavity after a canal wall–down mastoidectomy.

The following features of fatty tissue have been found to limit its use as an ideal obliteration material: a) Fatty tissue can only be used as a "filler", b) Because of its consistency, it cannot be used in the reconstruction of the ear canal wall in the way that musculoperiosteal flaps can. c) Fatty tissue becomes fibrotic, and gradually shrinks. We have noticed that all patients undergoing surgery for acoustic neuromas who had the cavity obliterated with fat developed extensive retraction postauricularly, and at repeat surgery carried out for other reasons, e. g., removal of residual tumor, the amount of fatty and fibrous tissue was reduced to a quarter of its original volume. The shrinkage of the fatty tissue starts soon after surgery, and postauricular retraction is visible within three months, and progresses over the first two years.

Possible Application of Fat Graft

In the author's opinion, after canal wall–down mastoidectomy for chronic ear disease, fatty tissue should only be used as one of the "fillers" in combined-graft obliteration techniques behind a new ear canal wall, reconstructed with soft tissue.

Obliteration with fatty tissue behind an intact ear canal wall, as in acoustic neuroma surgery, can be performed in cases of chronic ear disease, but any communication between the tympanic cavity and the mastoid cavity should be tightly closed.

Intact Canal Skin

In the following situations, fatty tissue can reasonably be used to replace other grafts as a "filler" of the cavity.

1. Obliteration of a canal wall–down mastoidectomy cavity in cases with intact ear canal skin, as used by Dagget (1949) (Figs. **255–257**). The attic perforation can be closed with fascia and the fat placed in the cavity, instead of blood (Fig. **257**).

2. Cavities formed after endaural surgical techniques with preservation of the canal wall skin, as described by Andrew (1956), can be obliterated using fat instead of blood, and the endaural incision can be sutured, as indicated in Figures **258** and **259**. Shrinkage of the fatty tissue will lead to diffuse enlargement of the ear canal and a small cavity, which is usually, however, selfcleaning.

Intact Bony Ear Canal Wall

1. Obliteration of the cavity with an intact posterior bony ear canal wall and scutumplasty. The attic is thightly separated from the tympanic cavity with cartilage, as indicated in Figures **381–385**, and in this situation fatty tissue can be placed behind the muscle grafts and cartilage grafts supplementing the obliteration. Shrinkage of the fatty tissue will result in retraction of the postauricular skin.

2. Fatty tissue can also be used in partial obliteration techniques after canal wall–up mastoidectomy and scutumplasty. Fatty tissue can supplement the obliteration lateral to the reconstructed attic, instead of using bone paté and fibrin glue (Figs. **385**, **386**).

3. In cases with *temporary displacement or temporary removal* of the bony ear canal wall and subsequent obliteration of the cavity, as described by Mercke (Fig. **524**), fatty tissue placed behind a Palva flap can supplement the obliteration, particularly in large cavities.

4. In the Farrior techniques, with the mastoid cavity behind an *intact and displaced* bony ear canal wall (Figs. **556–559**), fatty tissue can be used as an additional graft placed behind the muscle (Fig. **561**), or used instead of muscle. Similarly, in Olaizola's techniques, the cavity can be obliterated behind a tight closure of the aditus, instead of being ventilated (Figs. **566, 567**).

Reconstructed Ear Canal Wall

1. In techniques involving reconstruction of the ear canal wall in order to ventilate the cavity, it is sometimes desirable to obliterate such a cavity, or at least its lateral part, and leave only the medial part ventilated. In such situations (Fig. **814**), a plug of fatty tissue placed behind the Palva flap can be used.

2. In ear canal wall reconstructions using fascia and an *endaural approach* (Figs. **822**, **823**), a piece of fat can support the fascia laterally. Because of the difficulty of raising a large musculoperiosteal flap in an endaural approach, a fat graft could be used more often, e. g., in reconstructing the ear canal in an endaural approach using tragal cartilage (Figs. **825**, **826**). In this situation, a plug of fat obliterating the lateral part of the cavity, whilst still preserving the advantage of ventilation of the antrum and attic, is an option.

3. In reconstruction of the ear canal wall using autogenous tragal cartilage (Fig. **831**), allogenous septal cartilage (Fig. **833**), or knee cartilage (Figs. **834, 835**), the most lateral part of the cavity can be obliterated, either with muscle or a plug of fat.

4. Most methods of obliteration with muscle, as described in Chapter 18, can be supplemented by the use of a piece of fatty tissue in the most posterior part of a large cavity tucked behind the muscle tissue and the reconstructed ear canal wall. In obliteration techniques using a *superiorly-based* bipartite muscle flap (Figs. **891, 892**), or other superiorly based flaps (Figs. **878**, **899**) that are too short to completely obliterate the mastoid tip, a piece of fatty tissue can be used to fill this part of the cavity.

Palva flap obliteration is particularly suited to additional obliteration by fatty tissue, or other material (Figs. **927**, **931–939**, **941**). The fatty tissue can act as a "filler," instead of Gelfoam, which has often been used to fill the cavity behind the Palva flap (Fig. **931**).

With an obliteration using *inferiorly-based* a muscle flap, a particularly large mastoid tip can be obliterated with fatty tissue placed under the muscle. The same method can be used in the Naumann obliteration method behind an intact canal wall (Fig. **965**).

5. In obliteration of a canal wall–down mastoidectomy cavity using cartilage, additional tissue is sometimes needed. Fatty tissue could be placed behind a Palva flap and tragal cartilage, as shown in Figures **979**, **980**, and **985.**

In obliteration using hard tissue, the use of fatty tissue, with its tendency to shrink, is less appropriate. A canal wall reconstructed using hard tissue cannot retract, and may create irregularities within the cavity, with deep and dangerous retraction pockets. In obliteration techniques using bone paté behind cartilage and a Palva flap as described by Honda (Fig. **1009),** the lateral part of the cavity can be additionally obliterated using a plug of fat.

Fatty tissue can be used instead of muscle behind a cartilage plate in partial obliteration of the cavity (Chapter 14), either involving the sinodural angle, the mastoid tip, or of some perilabyrinthine air cells (Figs. **729**, **730).**

Adipose tissue can be used as additional filling material, mainly in the posterior or lateral parts of the cavity, in cases when insufficient muscle is available. However, for the relatively small amount of fatty tissue that is required, the surgeon may feel that it is not worthwhile to make an abdominal incision to harvest the fatty tissue. Usually, autogenous tissue is available around the mastoid process, and this can be used as free grafts, e. g., subcutaneous tissue, muscle, periosteum, bone pieces and bone paté, as well as cartilage. It is therefore understandable that fat is used only sporadically. The tendency for fatty tissue to shrink by about one-third during the first three months is also a great disadvantage. In the author's opinion, therefore, a fat graft, when used in the obliteration of a canal wall–down mastoidectomy cavity, should only be applied behind a reconstructed ear canal wall of soft tissue using a meatoplasty, so that the large cavity that results from shrinkage can be surveyed and cleaned.

Risk of AIDS

In several countries, regulations do not permit the use of any allogenous tissue unless it has been sterilized by boiling or in an autoclave. Even though storage of allogenous cartilage, dura, or ear drum in Cialit, formaldehyde, or alcohol will kill the HIV virus, the use of the allogenous cartilage, dura and ear drum has become impossible in these countries.

Allogenous cartilage, as used in scutumplasty (Figs. **360–364**) or in ear canal reconstruction, as described in Chapter 17 (Figs. **332–335**), can be replaced by autogenous tragal or conchal cartilage. Allogenous dura in ear canal wall reconstruction (Figs. **840–841**) can be replaced by fascia lata.

In obliteration with allogenous cartilage, as described in Chapter 19, however, the amount of available autogenous cartilage is inadequate to replace the allogenous cartilage (Figs. **973, 975, 981–990**). In this situation, fatty tissue can serve as a filler in a large cavity. Of course, other autogenous materials can also be used, such as muscles, subcutaneous tissue, bone paté and bone chips, or hydroxyapatite granules.

References

Abramson M, Lachenbunch P, Press B, et al. Results of conservative surgery for middle ear cholesteatoma. Laryngoscope 1977;87:1281–7.

Adkins WY, Osguthorpe JD. Use of composite autograft to prevent recurrent cholesteatoma caused by canal wall defects. Otolaryngol Head Neck Surg 1984; 92:319–21.

Aimi K. The clinical significance of epitympanic folds. Arch Otolaryngol 1971;94:499–508.

Aimi K. The tympanic isthmus: its anatomy and clinical significance. Laryngoscope 1978;87:1067–81.

Allam AF. Pneumatization of the temporal bone. Ann Otol Rhinol Laryngol 1969;78:49–64.

Altmann F. The fine structure of the auditory ossicles in otosclerosis. Arch Otolaryngol 1965;82:569–74.

Andrew WF. Modified radical mastoidectomy with reconstruction of the ear canal. Ann Otol Rhinol Laryngol 1956;65:201–13.

Anson B, Donaldson JA. Surgical anatomy of the temporal bone. 4th ed. New York: Raven Press, 1992

Aoki K, Esaki S, Honda Y. Effect of middle ear infection upon the pneumatization of the mastoid: an experimental study in pigs. Laryngoscope 1986:96:430–7.

Aoki K. Esaki S, Honda Y, Tos M. Effect of middle ear infection on pneumatization and growth of the mastoid process: an experimental study in pigs. Acta Otolaryngol 1990;110:399–409

Ars B, Ars-Piet N. Tympano-ossicular allograft tympanoplasty. Amsterdam: Kugler, 1993.

Austin DF. Mastoidplasty. Eye Ear Nose Throat Digest 1964;26:70–2.

Austin DF. The significance of the retraction pockets in the treatment of cholesteatoma: In: McCabe BF, Sadé J, Abramson M. eds. Cholesteatoma: first international conference. Birmingham, AL: Aesculapius, 1977:379–83.

Austin DF, Sanabria F. Mastoidplasty. Arch Otolaryngol 1962;76:414–21.

Austin DF, Shea JJ. A new system of tympanoplasty using vein graft. Laryngoscope 1961;71:596–611.

Babighian G. Posterior and attic wall osteoplasty in canal wall up tympanoplasty. J Laryngol Otol 1992a;l06:954–9.

Babighian G. Posterior and attic wall "en bloc" ostcoplasty in combined approach tympanoplasty. In: Nakano Y, ed. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1992b:649–53.

Bak-Pedersen K, Tos M. Mucous glands in the middle ear and osseous Eustachian tube in adult persons. Ann Otol Rhinol Laryngol 1973;82:80–9.

Ballance CA. Essays on the surgery of the temporal bone. London: Macmillan, 1919.

Barany R. Konservative Radikaloperation nach meiner Methode. Acta Otolaryngol 1921;3:22–3.

Barany R. Radikaloperation des Ohres. Vienna: Bennike, 1923.

Baron JH. Preservation of the cholesteatoma matrix in the modified radical mastoidectomy. Laryngoscope 1967;77:905–11.

Baron JH. Management of aural cholesteatoma in children. Otolaryngol Clin North Am 1969;2:71–88.

Baron S. Modified radical mastoidectomy: Preservation of the cholesteatoma matrix. A method of making a flap in the endaural technique. Arch Otolaryngol 1949;49:280–302.

Bauer M. Tympanoplasty after radical mastoid operation. Arch Otolaryngol 1967;86:387–90.

Beales PH. The problem of the mastoid segment after tympanoplasty. J Laryngol Otol 1959;73:527–31.

Beales PH. Hynes W. Rapid healing after mastoid surgery by use of the postauricular flap. J Laryngo Otol 1958;72:888–901.

van der Beek JMH, Kuijpers W. The mucoperiosteum of the middle ear in experimentally induced sterile otitis media. Acta Otolaryngol 1984;Suppl.414:71–9.

Bellucci RJ. Preservation of the posterior canal wall: the wide external auditory canal technique. Arch Otolaryngol 1973;97:198–200.

von Bergmann E. Die chirurgische Behandlung von Hirnkrankheiten. Berlin, 1889.

Betow C. Reconstruction of the middle ear and the posterior osseous wall of the auditory canal with homograft. Trans Am Acad Ophthalmol Otolaryngol 1975;80:573–6.

Bezold F, Siebenmann F. Textbook of Otology, trans. Holdinger J. Chicago: Cosgrove, 1908.

Björlin S. Fall av radikaloperation med plaslik från musc, tempor. och med bevared hörselsgang. Hygeia (Stockh) 1925;87:493–4.

Black B. Mastoidectomy reconstruction: use of aluminium templates to shape hydroxyapatite canal wall implants. Am J Otol 1991;12:426–8.

Black B. Prevention of recurrent cholesteatoma: use of hydroxyapatite plates and composite grafts. Am J Otol 1992;13:273–8.

Black B, Lomas A. Reconstruction of attic defects with hydroxyapatite. J Otolaryngol Soc Austral 1991;6:435–7.

Black B, Kelly S. Mastoidectomy reconstruction: revascularizing the canal wall repair. Am J Otol 1994;15:91–5.

Blair Simmons F, Shinn J, Keith W. Innervated temporal muscle mastoid flap. Arch Otolaryngol 1976;102:522–3.

Bluestone CD. Cantekin EI, Beery QC, et al. Functional eustachian tube obstruction in acquired cholesteatoma and related conditions. In: McCabe BF, Sade J, Abramson M, eds. Cholesteatoma: first international conference. Birmingham, AL: Aesculapius, 1977:325–35.

Bluestone CD, Cantekin EI, Beery QC, et al. Function of the eustachian tube related to surgical management of acquired antral cholesteatoma in children. Laryngoscope 1978:88:1155–63.

Bonding P, Hinrichsen J. Results of a modified canal wall up technique with obliteration in cholesteatoma. In: Tos M, Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989:871–3.

Bonding P, Tos M. Grommets in recurrent acute otitis media. ORL Dig 1976:38:10–12.

Bondy G. Totalaufmeislung mit Erhaltung von Trommelfell und Gehörknöchelchen. Monatsschr Ohrenheilkd (Vienna) 1910;44:15–23.

Bosch J. Reconstruction of bony canal wall defects in cholesteatoma surgery. In: Tos M, Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989:993–7.

Botey R. Drei Fälle von Attico-Antrotomie mit Vereinfachung der Autoplastik. Arch Ohrenheilkd 1898;45:68–74.

Bourdial J, Lallemant Y, Natali R. Le lambeau pédiculé retroauriculaire dans la chirurgie de l'otite chronique. Ann Otolaryngol (Paris) 1961;78:761–8.

Brandow C. Reconstruction of middle ear and posterior osseous wall of auditory canal with homograft reconstruction of old radical cavities. Trans Am Acad Ophthalmol Otolaryngol 1975;80:573–6.

Brask T. Obliteration of the mastoid cavity with crushed homograft cartilage in patients with cholesteatoma. In: Tos M, Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989:931–3.

Brunar M. Tympanoplastiken mit Erhaltung des Gehörganges. Arch Ohren-Nasen-Kehlkopfheilkd 1958;173:466–9.

Brunar M. Erhaltung und Restaurierung des Gehörganges bei Tympanoplastiken. Monatsschr Ohrenheilkd Laryngo-Rhinol 1959;93:1–7.

Caparosa R. An atlas of surgical anatomy and techniques of the temporal bone. Springfield: Thomas, 1972.

Carlowitz H. Totalaufmeisselung des Mittelohres vom Gehörgang aus. Arch Ohren-Nasen-Kehlkopfheilkd 1919;103:73–88.

Chan KH, Sculerati N, Casselbrant ML, Conwell DN, Bluestone CD. Comparison of eustachian tube function tests between children with cholesteatoma/retraction pocket and those with chronic otitis media with effusion. In: Tos M, Thomsen J, Petersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989:485–7.

Charachon R. La tympanoplastie. Grenoble: Presses Universitaires, 1990.

Charachon R, Roulleau P, Bremond G, et al. Les ossiculoplasties: état actuel. Paris: Arnette, 1987.

Charachon R, Gratacop B, Elbaze D. Anatomical and functional reconstruction of old radical mastoidectomy cavities by obliteration tympanoplasty. Clin Otolaryngol 1989;14:121–6.

Charland AR. New method of tympanoplasty. Laryngoscope 1960;70:1699–1712.

Chiossonc E. "Three cartilages" technique in intact canal wall tympanoplasty to prevent recurrent cholesteatoma. Am J Otol 1985; 6: 326–30.

Cody DTR, Taylor W. Mastoidectomy for acquired cholesteatoma: long-term results. In McCabe BF, Sadé J, Abramson M, eds. Cholesteatoma: first international conference. Birmingham, AL: Aesculapius, 1977:337–51.

Coetzee AS. Regeneration of bone in the presence of calcium sulfatc. Arch Otolaryngol 1980;106:405–9.

Cole RH. Ossicular replacement with selfstabilizing presculptured homogenous cartilages. Arch Otolaryngol 1982;108:560–2.

Collins EG.The problem of the mastoid segment in tympanoplasty. J Otol Laryngol 1964;78:1004–21.

Corgill DA, Martinez DM. Tympanoplasty: 125 cases without a cavity. South Med J 1963;56:296–301.

Crabtrec JA. Acute otitis and mastoiditis. In English, ed. Otolaryngology, vol. 1. Philadelphia: Harper and Row, 1985.

Dagget WI. Operative treatment of chronic suppurative otitis media. J Laryngol Otol 1949:63:635–46.

Dawlatly EE. Radical mastoid cavity reconstruction: the pedicled musculo-fascial flap. J Laryngol Otol 1992;106:124–6.

van Deinse JB, van den Borg RE. Atticoantrotomy with abdominal fat transplantation and myringoplasty. Pract Oto-Rhino-Laryngol 1958;20:327–32.

Diamant M. Otitis and pneumalization of the temporal bone: a clinical study – statistic analysis. Acta Otolaryngol 1940;suppl41:1–149.

Diamant M. Chronic otitis: a critical analysis. Pract Oto-Rhino-Laryngol 1952;14:125–38.

Djeric D, Savic D. Anatomical characteristics of the sinus epitympani anterior. Rev Laryngol Otol Rhinol 1985;106:205–7.

Eagleton WP. Unlocking of petrous pyramid for localized bulbar meningitis secondary to suppuration of petrous apex. Arch Otolaryngol 1931;13:386–422.

East CA, Brough MD, Grant HR. Mastoid obliteration with the temporoparietal fascia flap. J Laryngol Otol 1991;105:417–20.

Ekvall L. Total middle ear reconstruction. Acta Otolaryngol 1973; 75: 279–81.

Ekvall L. Personal communications, 1980 and 1987.

Elbrønd O. Obliteration of mastoid cavities in temporal bone surgery: eighty cases operated according to the method of Guilford. Arch. Otolaryngol 1963;78:132–7.

Eviatar H. Tragal perichondrium and cartilage in reconstructive ear surgery. Laryngoscope 1978;88(suppl11):l–23.

Falk B, Magnusson B. Eustachian tube closing failure: occurrence in retraction-type cholesteatoma. In: Tos M, Thomsen J, Petersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989: 477–80.

Farrior JB. Stapedectomy and tympanoplasty, part III: mastoidectomy, musculoplasty and tegmental fascia graft. Arch Otolaryngol 1962;76:338–45.

Farrior BJ. Tympanoplasty in 3-D. 3 vols. Tampa, FL: American Academy of Ophthalmology and Otolaryngology, 1968.

Farrior JB. The canal wall in tympanoplasty and mastoidectomy. Arch Otolaryngol 1969;90:706–14.

Farrior JB. Systematized approach to surgery for cholesteatoma. Arch Otolaryngol 1973;97:188–90.

Feldmann HH. Osteoplastische Meato-attiko-antrotomie. Laryngol Rhinol 1977;56:786–95.

Feldmann HH. Osteoplastic approach in chronic otitis media by means of microsurgical reciprocating saw. Clin Otolaryngol 1978;3:515–20.

Filipo R, Barbara M. Rehabilitation of radical mastoidectomy. Am J Otol 1986;7:248–52.

Filipo R, Barbara M. Rehabilitation of radical cavities. In: Babighian G and Veldmann JE, eds. Transplants and implants in otology. Amsterdam: Kugler and Ghedini, 1988:63–7.

Fisch U. Tympanoplasty and stapedectomy: a manual of techniques. Stuttgart: Thieme, 1980.

Fisch U. Tympanoplasty, Mastoidectomy and Stapes Surgery. Stuttgart: Thieme, 1994.

Fleischer K. Akute Mittelohrentzündung. Mastoiditis, Petrositis. In: Berendes J, Link R, Zöllner, F, eds. Hals-Nasen-Ohren-Heilkunde. 2nd ed., vol. 5. Stuttgart: Thieme, 1979.

Fleury P, Legent F, Lefebre C. Techniques chirurgicales de l'oreille. Paris: Masson, 1974.

Freerichs DW, Williams GV. One-stage endaural musculo-tympanoplasty. Arch Otolaryngol 1962;76:23–31.

Fritz MH, Crawford GB. An evaluation of the Rambo primary closure of the radical mastoidectomy wound. Trans Am Acad Ophthalmol Otolaryngol 1960;64:159–67.

Gabe E. Über plastischen Verschluß persistierenden retroaurikulären Öffnungen nach Antrumopcrationen. Passow Beitr Ohr Nas Hals (Berl) 1911;4:354–75.

Gacek RR. Surgical landmark for the facial nerve in the epitympanum. Ann Otol Rhinol Laryngol 1980;89:245–50.

Gans H, Wlodyka J. Mastoid pneumalization in chronic otitis media. Arch Otolaryngol 1966;83:343–6.

Gerlach H. Die hintere Gchörgangswand bei der Tympanoplastik. Monatsschr Laryngol Rhinol Otol 1969a;48:214–18.

Gerlach H. Die bilaterale Ausräumung des Cholesteatoms. Arch Ohren-Nasen-Kehlkopfheilkd 1969b;194:642–65.

Gerlach H. Verwendung von lyophylisierter Dura mit Histoacrylgewebekleber bei der Rekonstruktion der hinteren Gehörgangswand. HNO (Berlin) 1970;19:202–20.

Gerlach H. Die Verwendung von Kortikalisknochen zur Vermeidung von Retraktionsnischen bei Cholesteatomoperationen. Monatsschr Laryngol Rhinol Otol 1979;58:413–16.

Gersdorff MCH, Maisin JP. Anatomy of the retrotympanum. In: Ars, ed. Medical Congress Series No. 5. Brussels: Medical Media International, 1984:310–15.

Gersdorff MCH, Garin P. Notre technique de revalidation des cavités d'évidement pétro-mastoidien. Rev Laryngol 1992;113:427–92.

Gersdorff MCH, Rabillard TAJ. Revalidation of radical mastoidectomy cavities: reconstruction with bone dust and biomaterials. Am J Otol 1987; 8: 133–5.

Geyer G, Helms J. Reconstructions of the posterior auditory canal wall and obliteration of the mastoid cavity using glassinomer cement. In: Yanagihara N, Suzuki JI, eds. Transplants and implants in otology, II. Amsterdam: Kugler, 1992:165–70.

Gibb A. Tympano-mastoid surgery. J Laryngol Otol 1977;91:501–10.

Glasscock ME. Surgical technique for open mastoid procedures: how I do it. Laryngoscope 1982;92:1140–2.

Glasscock ME, Miller GW. Intact canal wall tympanoplasty in the management of cholesteatoma. Laryngoscope 1976;86:1639–57.

Glasscock ME, Shambaugh GE. Surgery of the ear. 4th ed. Philadelphia: Saunders, 1990.

Goodhill V. Tragal perichondrium, oval window graft. Laryngoscope 1961;71:975–83.

Goodhill V. Tragal perichondrium and cartilage in tympanoplasty. Arch Otolaryngol 1967;85:480–91.

Goodhill V. Ear diseases, deafness and dizziness. New York: Harper and Row, 1978.

Goycoolea MV, Paparella MM, Nissen RL. Atlas of otologic surgery. Philadelphia: Saunders, 1989.

Grahne B. Cavity filling technique in mastoid surgery. Acta Otolaryngol 1963;56:437–44.

Grote JJ, Blitterswijk CA. Reconstruction of the posterior auditory canal wall with a hydroxyapatite prosthesis. Ann Otol Rhinol Laryngol 1986;95(suppl 123):6–9.

Grote JJ, Luttgert HW. Cavity reconstruction with hydroxyapatite canal wall prosthesis. In: Tos M, Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler. 1989:1013–19.

Gundersen T. The use of postauricular flap in mastoid surgery. Acta Otolaryngol 1961;53:45–8.

Guns P. La cure radicale des otorhées chroniques par la conduit et ses résultats physiologiques. Rev Laryngol (Bord) 1933;54:1102–31.

Guilford FR. Controlled cavity healing after mastoid and fenestration operations. Arch Otolaryngol 1960;71:165–71.

Guilford FR. Obliteration of the cavity and reconstruction of the auditory canal in temporal bone surgery. Trans Am Acad Ophthalmol Otolaryngol 1961;65:114–22.

Guilford FR, Wright WK, Draper WL. Controlled healing of mastoid and fenestration cavities. Trans Am Acad Ophthalmol Otolaryngol 1958;62:455–65.

Gycrgyay A. Radikaloperation der Mittelohren vom Gehörgang aus mit Instrumenten, die von innen nach außen arbeiten. Arch Hals- Nasen- Ohrenheilkd 1923;6:392–8.

Gyo K, Hirata Y, Yanagihara N. Management of canal wall defects in staged canal up tympanoplasty. In: Yanagihara N, Suzuki Y, eds. Transplants and implants in otology, II. Amsterdam: Kugler, 1992:175–8.

Hagerty RR. Viable and non-viable human cartilage homograft. Surg Gynecol Obstet 1967;125:485–92.

Hammar JA. Studien über die Entwicklung des Vorderdarms und einigen angrenzender Organe. Arch Mikrosk Anal 1902;59:471–628.

Hasselt van AC, Liu KG. Optimal healing of the radical cavity utilizing the "Hong Kong" vascularized temporalis fascia flap. In: Nakano Y, ed. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1993:711–16.

Härma R, Koskinen O Mastoid osteoplasty with anorganic bone. Act Otolaryngol 1965;59:81–7.

Heermann H. Zur Frage der Plastik bei Gehörgangsradikaloperationen. Z Hals- Nasen- Ohrenheilkd 1930;26:35–41.

Heermann H. Zur Radikaloperation durch den operativ erweiterten Gehörgang. Z Hals- Nasen- Ohrenheilkd 1934;36:346–9.

Heermann H. Johannes Kessel and the history of endaural surgery. Arch Otolaryngol 1969;90:136–41.

Heermann H, Heermann J. Endaurale Chirurgie/Endaural surgery. Munich: Urban and Schwarzenberg, 1964.

Heermann J Sr. Übersichtiche Freilegung des Kuppelraumes und der Warzenfortsetzhöhle vom Gehörgang aus (Totalaufmeißlung). Arch Ohr-Nas-Kehlkheilkd 1921;108:54–8.

Heermann J Jr. Erfahrungen mit frei transplantierten Fascien – Bindegewebe des Muskulus temporalis bei Tympanoplastik und Verkleinerung der Radikalhöhle. Knorpelbrücke von Stapes zum unteren Trommelfellrand. Z Laryngol 1962;41:141–55.

Heermann J. Surgery of the oval window in otosclerosis. J Laryngol Otol 1963;42:698–708.

Heermann J. Autograft tragal and conchal palisade cartilage and perichondrium in tympanomastoid reconstruction. Ear Nose Throat J 1992;91:1–6.

Heermann R, Riehm J. Verlauf des Sinus sigmoideus und Pneumatisation des Warzenfortsatzes. Zugleich ein Beitrag zur Frage der sekundären Sklerosierung des Warzenfortsatzes. HNO (Berlin) 1961;9:129–31.

Hildmann H. Offene oder geschlossene Technik der Tympanoplastik. Bemerkungen zur Erhaltung der hinteren Gehörgangswand. Laryngol Rhinol Otol 1991;70:335–9.

Hilger JA, Hohmann A. The pedicle graft in tympanomastoid surgery. Laryngoscope 1962;72:1121–4.

Hoffmann F. Beitrag zur Untersuchung des äußeren Gehörgangs. Caspers Wochenschr gesamte Heilk 1841;10:1–15.

Hoffmann R. Über den chronischen Ohrenfluß. Korrespondenzbl Allg Ärztl Ver Thüring 1892;7:238.

Holmgren G. Some experience in surgery for otosclerosis. Acta Otolaryngol 1923;5:460–6.

Honda Y. My tympanoplasty. 1992. Oto-Rhino-Laryngology Tokyo 1992:35(suppl 5);1–127.

Horn KL, Brackmann DE, Luxford WM, Shea JJ III. The anterior epitympanic recess in cholesteatoma surgery. Ann Otol Rhinol Laryngol 1986;95:12–15.

Hoshino T. Surgical anatomy of the anterior epitympanic space. Arch Otolaryngol Head Neck Surg 1988;114:1143–5.

Hoshino T, Suzuki J. Anterior attic wall anatomy. Arch Otolaryngol Head Neck Surg 1978;104:588–90.

House WF, Luetje CM. Acoustic tumors. 2 vols. Baltimore: University Park Press, 1979.

House WF, Sheehy JL. Functional restoration in tympanoplasty. Arch Otolaryngol 1963;78:304–9.

Högset O, Bredberg G. Plaster of Paris – thermal properties and biocompatibility: a study on an alternative implant material for ear surgery. Acta Otolaryngol 1986;101:445–52.

Högset O, Bredberg G. Plaster of Paris and hair cell morphology: A scanning electron microscopic study on an alternative implant material for ear surgery. Acta Otolaryngol 1988;106:331–8.

Högset O, Bredberg G. Reconstruction of radical cavities with plaster of Paris. In: Yanagihara N, Suzuki YI, eds. Transplants and implants in otology. Amsterdam: Kugler, 1992:149–54.

Hörmann K, Donath K. Is hydroxyapatite ceramic an adequate biomaterial in ossicular reconstruction? Am J Otol 1987;8: 402–5.

Ikarashi H, Nakano Y. The effect of chronic middle ear inflammation on the pneumatization of the tympanic bulla in pigs. Acta Otolaryngol 1987; 104: 130–7.

Jako G. The posterior bony ear canal wall and the antrum threshold angle in conservative middle ear surgery. Laryngoscope 1966;76:1260–76.

Jansen C. Über Radikaloperationen und Tympanoplastik. Sitz Berl Fortbild Ärztekamm Ob.v.p.4, 18. Febr. 1958.

Jansen C. Die Erhaltung des äußeren Gehörganges bei der Radikaloperation und eine neue Art der Tympanoplastik. Zentralbl HNO 1962;74:36.

Jansen C. Cartilage tympanoplasty. Laryngoscope 1963;73:1288–1302.

Jansen C. The combined approach for tympanoplasty. J Laryngol Otol 1968;82:771–93.

Jansen C. Posterior tympanotomy: experiences and surgical details. Otolaryngol Clin North Am 1972;5:79–96.

Jansen C. Intact canal wall tympanoplasty. In: Shambaugh G, Shea J, eds. Fifth International Workshop on middle ear microsurgery. Huntsville: Strode, 1977:370–5.

Jasser 1776 [cited in Schwartze and Eysell 1873].

Jongkees LBW. Reconstructive surgery of the middle ear in active chronic otitis. Pract Oto-Rhino-Laryngol 1957;19:107–24.

Kadariu E. The use of a fatty transplant in the functional surgery of the ear. Vestn Otorinolaringol 1960;22:48–51.

Kahramanyol M. Fascioperiosteal flap in neo-osteogenesis in radical mastoidectomy. Ear Nose Throat J 1992;71:70–7.

Kawamura S, Okabe K, Mogi S, Terao A. The normal development of the mastoid pneumatic cells. J Otorhinolaryngol Soc Tpn 1963;66:909–12.

Kessel J. Über das Mobilisieren des Steigbügels durch Ausschneiden des Trommelfells, Hammers und Ambosses bei Undurchgängigkeit der Tube. Arch Ohrenheilkd 1878:13:69–88.

Kessel J. Über das Ausschneiden des Trommelfells und Mobilisieren des Steigbügels. Arch Ohren- Nasen- Kehlkopfheilkd 1880;16:196–8.

Kessel J. Über die Behandlung des chronischen eitrigen Mittelohrentzündungen. Arch Ohren- Nasen- Kehlkopfheilkd 1888;26:246–7.

Kettel K. Peripheral facial palsy.: Pathology and surgery. Munksgaard, Copenhagen, 1959.

Kinney SE. Five years' experience using the intact canal wall tympanoplasty with mastoidectomy for cholesteatoma: preliminary report. Laryngoscope 1982;92:1396–1400.

Kisch H. The use of muscle grafts in mastoid obliteration. Postgrad Med J 1932;8:270–1.

Klestadt W. Zur Technik der Plastik nach der Aufmeißelung. Zentralbl Hals- Nasen- Ohrenheilkd 1933;193:19–703.

Kley W. Surgical treatment of chronic otitis media and its immediate consequences. In: Naumann HH, ed. Head and neck surgery, vol. 3: Ear. Stuttgart: Thieme, 1982:171–265.

Kopetsky SJ. Otologic Surgery, 2nd ed. New York: Hoeber, 1929.

Kopetsky SJ, Almour R. Suppuration of petrous pyramid: pathology, symptomatology and surgical treatment. Ann Otol Rhinol Laryngol 1931;40:157–77.

Körner O. Über Gehörplastik, 3. Verh Dtsch Otol Ges 1894;1:110–25.

Körner O. Die eitrigen Erkrankungen des Schläfenbeins. Wiesbaden, Germany: Bergmann, 1899.

Kuhweide W, van Deinse JB. The surgical treatment of chronic otitis media. Acta Otolaryngol 1960;52:143–9.

Kuipers W. Behavior of bioimplants in the middle ear: an experimental study. In: Grote JJ, ed. Proceedings of the first international symposium on biomalerial in otology. Leiden: Nijhoff, 1984:18–28.

Landolfi M, Taibah A, Russo A, Szymanski M, Shaan M, Sauna M. Revalidation of the Bondy technique. In: Nakano Y, ed. Cholesteatoma and mastoid Surgery. Amsterdam: Kugler, 1993:719–21.

Lathorp FD. Endaural atticomastoidectomy: an evaluation. Laryngoscope 1943;53:589–601.

Lapidot A, Brandow EC. A method for preservation the posterior canal wall and bridge in surgery for cholesteatoma: preliminary report. Acta Otolaryngol 1966;62:88–92.

Lau T, Tos M. Treatment of sinus cholesteatoma: long-term results and recurrence rate. Arch Otolaryngol 1988a;9:456–64.

Lau T, Tos M. Sinus cholesteatomas: recurrences and observation time. Acta Otolaryngol 1988b; suppl 449:191–3.

Lau T, Tos M. Tensa retraction cholesteatoma: treatment and long-term results. J Laryngol Otol 1989;103:149–57.

Lempert J. Radikal subcortical mastoidectomy. Ann mal Oreille 1929;48:111–37.

Lempert J. Complete apicectomy (mastoidotympanoapicectomy), new technique for complete apical exenteration of apical carotid portion of petrous pyramid. Arch Otolaryngol 1937;25:144–77.

Lempert J. Improvement of hearing in cases of otosclerosis: new one stage surgical technique. Arch Otolaryngol 1938;28:42–97.

Lempert J. Fenstra nova ovalis: a new oval window for the improvement of hearing in cases of otosclerosis. Arch Otolaryngol 1941;34:880.

Lenis A. Hydroxyapatite canal wall reconstruction in patients with otologic dilemmas. Am J Otol 1990;11:411–14.

Lewis MD. A variation in technique of facial decompression. Laryngoscope 1956;66:1451–63.

Lin IF. A new external canal wall preserving method for antral cholesteatoma surgery: the osteocutaneous flaps. Kao Hsiung I Hseneh Tsa Chih 1990;6:149–54.

Linde RE. The cartilage perichondrium graft in the treatment of posterior tympanic membrane retraction pockets. Laryngoscope 1973;83:747–53.

Maffei G, Zini C. Trapianti e implantati in otolaringoiatri. Sassari: Gallizzi, 1972.

Magnan J, Bremond C. Les conditions de guérison de l'otite chronique cholestratomateuse. Ann Oto-Laryngol (Paris) 1985;102:565–73.

Magnan J, Chays A, Gignac D, Bremond G. Reconstruction of posterior canal wall: long-term results. In: Charachon R, Garcia-Ibanez E, eds. Long-term results and indications in otology and otoneurosurgery. Amsterdam: Kugler. 1991:57–61.

Mahoney JL. Tympanoacrvloplasty. Arch Otolaryngol 1962: 75: 519–23.

Marquet J. Eradication of cholesteatoma. In: Tos M, Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler. 1989:811–16.

Mayer O. Eine Methode der Transplantation von Hautlappen bei der Totalaufmeißelung der Mittelohrräume. Arch Ohren- Nasen- Kehlkopfheilkd 1916;98:146–51.

Mayer VO. Implantation von gestielten Periost und Muskellappen bei Antrumfisteln. Monatsschr Ohrenheilkd 1917;51: 691–2.

McCleve DE. Tragal cartilage in reconstruction of the auditory ear canal. Arch Otolaryngol 1969;90:271–4.

McCleve DR. Repair of bony canal wall defects in tympanomastoid surgery. 1985;6:76–8.

Mercke U. Anatomic findings one year after combined approach tympanoplasty. Am J Otol 1986;7:150–54.

Mercke U. The cholesteatomatous ear one year after surgery with obliteration technique. Am J Otol 1987;8:534–6.

Meuser W. Obliteration des Warzcnfortsatzes mil Palacos R zur Verhütung von Cholesteatom-Rezidiven. Laryngol Rhinol 1980; 59:116–21.

Meuser W. Obliterating the mastoid cavity with plastic bone cement: a way of avoiding cholesteatoma recurrences. In: Sadé J, ed. Cholesteatoma and mastoid surgery. Amsterdam: Kugler. 1982:503–8.

Meuser W. Permanent obliteration of old radical mastoid cavities combined with tympanoplasty. J Laryngol Otol 1983; 98: 31–5.

Meuser W. The Wuppertal concept of cholesteatoma surgery (ECHO). In: Tos M. Thomsen J. Peitersen E. eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler. 1989:913–20.

Meuser W. Endaural cholesteatoma operation (ECHO) types I–V: a comprehensive concept. In: Nakano Y. ed. Cholesteatoma and mastoid surgery. Amsterdam: Kugler 1993: 775–83.

Meurmann Y, Ojala L. Primary reduction of a large operation cavity in radical mastoidectomy with a muscle–periosteal flap. A'cta Otolaryngol 1949;37:245–52.

Mill WA. Three cases of conservative mastoid operation with temporal muscle graft. Zentralbl Hals- Nasen- Ohrenheilkd 1931;16:128–9.

Miyajima I, Honda Y. Clinical significance of the tympanic isthmus related to the development of cholesteatoma. Auris Nasus Larynx 1986;12:149–55.

Morimitsu T. Illustrated ear surgery. Tokyo: Medical Illustration. 1991.

Morimitsu T, Nagai T, Nagai M. et al.: Pathogenesis of cholesteatoma based on clinical results of anterior tympanotomy. Auris Nasus Larynx 1989;16(suppl1):9–14.

Mosher HP. A method of filling the excavated mastoid with a flap from back of the auricle. 1911;21:1156–63.

Myers D, Schlosser WD. Anterior–posterior technique for the treatment of chronic otitis media and mastoiditis: preliminary report. Laryngoscope 1960;70:78–83.

Müsebeck K. Die Mastoidplastik is gcschlossenen, rekonstruierenden. offenen oder obliterierenden Verfahren. Z Laryngol Rhinol 1970;49:361–8.

Nadal D, Heermann P, Baumann A, van Coni A. Acute mastoiditis: clinical, microbiological, and therapeutical aspects. EUR Paediatr 1990;149:560–4.

Nakano Y. Cholesteatoma surgery and mastoid obliteration In: Nakano Y, ed. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1993:769–73.

Naumann HW. Die operative Behandlung des Warzenfortsatzes bei Otitis media chronica. Z Rhinol Laryngol 1966;45:687–99.

Nelson RA. Temporal bone surgical dissection manual. Los Angeles: House Ear Institute, 1983.

Olaizola GF. El cholesteatoma. Penencia oficial de la Sociedad Española de ORL. Madrid: Garsi. 1985:207–13.

Olaizola GE Tympanoplasty: 5-year review of results using the on demand AAD technique. Am J Otol 1988;9:318–22.

Olaizola GF, Gamboa J, Alaminos D. Tympanoplasty on demand, antrum exclusion, attic elimination (DAA). In: Tos M. Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989:989–91.

Palva T. Reconstruction of ear canal in surgery for chronic ear. Arch Otolaryngol 1962a;75:329–35.

Palva T. A new approach to radical surgery of the chronic otitis media. Pract Otorhinolaryngol 1962b;24:372–82.

Palva T. Reconstruction of ear canal and middle ear in chronic otitis. Acta Otolaryngol 1963a; (suppl 188):228–33.

Palva T. Surgery of chronic ear without cavity: results in 130 cases with musculoperiosteal flap and fasciotympanoplasty. Arch Otolaryngol 1963b;77:570–80.

Palva T. Surgical control of the mastoid segment in chronic ear disease in 1988. Arch Oto-Rhino-Laryngol 1989;246:274–6.

Palva T, Mäkinen J. The meatally based musculoperiosteal flap in cavity obliteration. Arch Otolaryngol 1979;105:377–80.

Palva T, Palva A. Size of the human mastoid air cell system. Acta Otolaryngol 1966;62:238–51.

Palva T, Friedmann I, Palva A. Mastoiditis in children. J Laryngol Otol 1964;78:977–91.

Palva T, Palva A, Kärjä J. Cavity obliteration and ear canal size. Arch Otolaryngol 1970;92:366–71.

Palva T, Virtanen H, Mäkinen J. Acute and latent mastoiditis in children. J Laryngol Otol 1985;97:127–36.

Panis R. Haid T, Schcele J. Die Anwendung eines Fibrinklebers zur Rekonstruktion der hinteren Gehörgangswand. Z Laryngol Rhinol 1979;58:400–8.

Pause R. Stacke's Operationsmethode zur Freilegung der Mittelohrräume während des ersten Jahres ihrer Anwendung in der Ohrenklinik zu Halle. Arch Ohrenheilkd 1893:34:248–280.

Paparella MM, Jung TTK. Intact bridge tympanomastoidectomy (IBM): combined essential features of open vas. closed procedures. J Laryngol Otol 1983;97:575–85.

Paparella MM, Jung TTK. Intact bridge tympanomastoidectomy. Otolaryngol Head Neck Surg 1984;92:334–8.

Paparella MM, Shumrick DA. Otolaryngology. 3 vols. Philadelphia: Saunders, 1988.

Pappas JJ, Bailey HAT, McCrew RN, Graham SS. Homograft septal cartilage for attic support in intact canal wall tympanomastoidectomy and tympanoplasty. Laryngoscope 1981;91:1457–62.

Paulsen K. Einführung in die rekonstruktive Mikrochirurgie des Mittel- und Innenohres. Stuttgart: Schattauer, 1974.

Peck D. Musculoplasty and temporal bone procedures. Arch Otolaryngol 1961;74:677–81.

Penha G. The value of adipose tissue grafts in otorhinolaryngology. Rev Port Obstet Ginec Cir 1951;4:134–40.

Perkins R. Tympanomastoid reconstruction: an operative procedure for anatomical and functional reconstruction of the radicalized ear. Laryngoscope 1976;86:416–30.

Petit JL. Traité des maladies chirurgicales. Paris: 1774.

Piquet J, Decroix G. Leroy L. Petromastoid clearance with inclusion of fat: anatomical and functional results. Ann Otolaryngol 1958;75:491–501.

Plester D. Tympanic membrane homografts in ear surgery. Acta Otolaryngol 1970;24:34–7.

Plester D, Hildmann H, Steinbach E. Atlas der Ohrchirurgie. Stuttgart: Kohlhammer, 1989.

Popper O. Periosteal flap grafts in mastoid operations. Afr Med J 1935;9:77–83.

Portmann M. Le conduit auditif externe osseux dans les tympanoplasties. Rev Laryngol 1966;87:975–84.

Portmann M. The ear and temporal bone. New York: Masson. 1979.

Pou JW. Mastoid surgery in chronic otitis media without creating a mastoid cavity. South Med J 1960;53:1133–7.

Pou JW. Reconstruction of bony canal with autogenous bone graft. Laryngoscope 1977;87:1826–32.

Preobrazhensky NA. Melanin VD. Mastoidplasty with formaldehyde solution: stored bone and cartilage. Arch Otolaryngol 1977:103:567–9.

Prescut CA. Mallan JF. Mastoid surgery at the Red Cross War Memorial Children Hospital 1986–88. J Laryngol 1991;105:409–12.

Preysing J. Zur Plastik bei und nach Ohroperationen. Med Klin 1910;481:896–8.

Proctor B. The development of the middle ear spaces and their surgical significance. J Laryngol Otol 1964;78:631–47.

Proctor B. Surgical anatomy of the posterior tympanum. Ann Otol Rhinol Laryngol 1969;78:1026–41.

Proctor B. Attic–aditus block and the tympanic diaphragm. Ann Otol Rhinol Laryngol 1971;80:371–5.

Proctor B. Surgical anatomy of the ear and temporal bone. Stuttgart: Thieme, 1989.

Proctor B, Nielsen E, Proctor C. Petrosquamous suture and lamina. Otolaryngol Head Neck Surg 1981;89:482–95.

Qvarnberg Y. Acute otitis media: a prospective study of myringotomy and antimicrobial treatment. Acta Otolaryngol 1981;suppl375:1–157.

Rainer A. Untersuchungen über die Entwicklung und den Ausbau der Pyramidenzellen. Arch Ohren- Nasen- Kehlkopfheilkd 1938; 145: 3–49.

Ramadier J. Les ostéites pétreuses profondes (pétrosites). Oto-Rhino-Laryngol Int 1933;17:816–21.

Rambo JHT. A new obliteration to restore hearing in conductive deafness of chronic suppurative otitis. Arch Otolaryngol 1957;66:525–32.

Rambo JHT. Muscoloplasty: a new operation for suppurative middle ear deafness. Trans Am Acad Ophthalmol Otolaryngol 1958;62:166–77.

Rambo JHT. Musculoplasty for restoration of hearing in chronic suppurative ears. Arch Otolaryngol 1969;89:184–190.

Rasmussen F. Incidence of simple matoidectomies in Denmark. Unpublished data, presented at the annual meeting of the Danish Otosurgical Society, October 1986.

Reck R. Rekonstruktion der hinteren Gehörgangswand mit ceravitalprotesen. HNO (Berlin) 1985;33:162–5.

Redfield N. Bone paste scutoplasty with attic stent. In: Tos M. Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989:857–60.

Richards SH. Tympanoplasty results following the mobile bridge technique. Trans Am Acad Ophthalmol Otolaryngol 1972;76:153–9.

Richter VR. Über Aufmeißelung der Ohren vom Gehörgang aus. Z Hals- Nasen- Ohrenheilkd 1922;2:376–8.

Richtner NG. Reconstructive microsurgery of the ear especially with the cavum minor technique. Laryngoscope 1960; 70: 1179—91.

Ringenberg JC. Fat graft tympanoplasty. Laryngoscope 1962;72:188–92.

Ringenberg JC, Fornatto EJ. The fat graft in middle ear surgery. Arch Otolaryngol 1962;76:407–13.

Robinson JM. Closed cavity tympano-mastoidectomy. In: Tos M, Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989:839–41.

Rosborg J. Long-term results of anterior atticotomy in the treatment of attic cholesteatomas. In: Nakano Y, ed. Cholesteatoma and mastoid surgery: proceedings of the fourth international conference, Niigata, Japan. Amsterdam: Kugler, 1993, 667–9.

Rubensohn G. Mastoid penumatization in children at various ages. Acta Otolaryngol 1965;60:11–14.

Sadé J. Postoperative cholesteatoma recurrence. In: McCabe BF, Sadé J, Abramson M, eds. Cholesteatoma: first international conference. Birmingham, AL: Aesculapius, 1977:284–9.

Sadé J. Secretory otitis media and its sequelae. New York: Churchill Livingstone, 1979.

Sakai M, Shinkawa A, Miyake H. Fuji K. Reconstruction of scutum defects (scutumplasty) for attic cholesteatoma. Am J Otol 1986;7:188–92.

Salen B. Myringoplasty using septum cartilage. Acta Otolaryngol 1963;suppl 188:82–91.

Sanna M. Personal communication, 1994.

Sanna M, Gamoletti R, Bartesi G, Jemmi G, Zini C. Posterior canal wall atrophy after intact canal wall tympanoplasty. Am J Otol 1986;1:74–5.

Sato H, Akihiko F, Nakurama H, Naito Y, Honjo I. Eustachian tube function in children with cholesteatoma. In: Tos M, Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989:489–92.

Saunders WH, Paparella MM. Atlas of ear surgery. St. Louis: Mosby, 1971.

Savic D, Djeric D. Morphological variations and relations of the epitympanum. Rev Laryngol 1986;107:61–4.

Savic D, Djeric D. Anatomical variations and relations of the medial and lateral portions of the attic and their surgical significance. J Laryngol Otol 1987;101:1109–17.

Schiller A. Mastoid osteoplasty using autogenous cancellous bone: progress report and modified technique. J Laryngol Otol 1961;75:647–88.

Schiller A. Mastoid oestoplasly. Arch Otolaryngol 1963;77:475–83.

Schiller A, Singer M. Mastoid osteoplasty using autogenous cancellous bone: a new procedure. S Afr Med J 1960;34:645–50.

Schnee IM. Tympanoplasty: a modification in technique. Arch Otolaryngol 1963;77:87–91.

Schnee IM. Choice of technic in tympanoplasty. Eye Ear Nose Throat Monthly 1964;43:43–7.

Schnee IM. Methods and results of tympanoplasty. J Med Soc New York 1969;66:616–18.

Schobel H. Tympanoplasty following previous radical mastoidectomy. In: Tos M, Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989:1019–25.

Schuknecht HF. Gulya AJ. The anterior epitympanic recess. In: Anatomy of the temporal bone with surgical implications. Philadelphia: Lea and Febiger, 1986:89–90.

Schullmann A, Rock EH. Koerners's (petrosquamous) septum in otology. Arch Otolaryngol 1972;96:124–9.

Schwaber MK. Intact canal wall mastoidectomy. Am J Otolaryngol 1979;1:45–8.

Schwarlze HH, Eysell CG. Übcr die künstliche Eröffnung des Warzenfortsatzes. Arch Ohrenheilkd 1873;7:157–87.

Shambaugh GE Jr. Involvement of the jaw joint in acute suppurative otitis media. Arch Otolaryngol 1941;33:975–81.

Shambaugh GE. Surgery of the ear. 1st ed. Philadelphia: Saunders, 1959.

Shambaugh GE, Glasscock ME III. Surgery of the ear. 3rd ed. Philadelphia: Saunders, 1980.

Shea MC, Gardner G Jr. Mastoid obliteration using homograft bone: preliminary report. Arch Otolaryngol 1970;92:358–65.

Shea JJ, Homsy CA. The use of Proplast in otologic surgery. Laryngoscope 1974;84:1835–45.

Sheehy JL. Surgery of chronic otitis media. In: Coates BM, Schenk HD, Miller MV, eds. Otolaryngology, Chapter 10B. Hagerstown: Prior, 1965.

Sheehy JL. Tympanoplasty with mastoidectomy: a reevaluation. Laryngoscope 1970a;80:1212–30.

Sheehy JL. Intact canal wall technique in management of aural cholesteatoma. Laryngoscope 1970b;84:1–31.

Sheehy JL. Surgery of chronic otitis media. In: English GM, ed. Otolaryngology, vol. 2. Hagerstown: Harper and Row, 1972:1–86.

Sheehy JL. Cholesteatoma surgery: canal wall down procedures. Ann Otol Rhinol Laryngol 1988;97:30–5.

Sheehy JL. Surgery for chronic otitis media. In: English GM, ed. Otolaryngology. 2nd ed., vol. 1. Philadelphia: Lippincott, 1990:1–86.

Sheehy, JL, Patterson MF. Intact canal wall tympanoplasty with mastoidectomy: a review of eight year's experience. Laryngoscope 1967;77:1502–42.

Sheehy JL, Brackmann D, Graham M: Cholesteatoma surgery: residual and recurrent disease. A review of 1024 cases. Ann Otol Rhinol Laryngol 1977;86:451–62.

Sheridan MR. Radical and modified radical operation without a meatal flap. J Laryngol Otol 1943;58:424–5.

Sheridan MR. Modified radical operation with meatal preservation and with observations on hearing in the operation described. J Laryngol Otol 1950;64:219–32.

Shinkawa A, Sakai M. Obliteration of the mastoidal cavity in cholesteatoma. In: Sacristan T, Alvarez-Vincent JJ, Antoli-Candela F, et al, eds. Otolaryngology, head and neck surgery. Amsterdam: Kugler, 1990:521–6.

Shinkawa A, Sakai A. Ossicular reconstruction with ceramic prosthesis in cholesteatoma surgery. In: Yanagihara N, Suzuki J, eds. Transplants and implants in Otology, II. Amsterdam: Kugler, 1992:117–22.

Siebenmann F. Radikaloperation des Cholesleatomes mittels Anlegung breiter permanenter Öffnungen gleichzeitig gegen den Gehörgang und gege n die retroaurikuläre Region. Berl Klin Wochenschr 1893;30:12–4, 1893;30:43–5.

Siim C, Tos M. Partial and total reconstruction of old radical cavities: long-term results. Arch Otolaryngol 1987;44:635–43.

Siim C, Tos M. Cavity problem after total reconstruction of old radical cavities. In: Tos M, Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler. 1989:1001–5.

Smith MFW. Reconstruction of the open mastoidectomy ear: a six-year progress report. Ann Otol Rhinol Laryngol 1975;84:552–7.

Smith MJ. Indications and technique of the different operations for chronic mastoiditis. Surg Gynecol Obstet 1931;52:442–5.

Smith PG, Stroud H. Goebel JA. Soft-wall reconstruction of the posterior external ear canal wall. J Otolaryngol Head Neck Surg 1986;94:355–9.

Smyth GDL. Preliminary report of the technique in tympanoplasty designed to eliminate the cavity problems. Laryngoscope 1962;76:460–3.

Smyth GDL. Combined approach tympanoplasty. Arch Otolaryngology 1969;89:250–1.

Smyth GDL. Postoperative cholesteatoma in combined approach tympanoplasty: fifteen-year report on tympanoplasty, part 1. J Laryngol Otol 1976;90:597–621.

Smyth GDL. Chronic ear disease. Edinburgh: Churchill Livingstone, 1980.

Smyth GD, Dowe AC. Cartilage canalplasty. Laryngoscope 1971;81:786–92.

Smyth GDL, England RM, Gibson B, Kerr AC. Posterior tympanotomy: its importance in combined approach tympanoplasty. J Laryngol Otol 1967;81:69–74.

Smyth GDL, Kerr AC, Goodey RJ. Current thoughts on combined approach tympanoplasty, II: restoration of the sound transformer mechanism. J Laryngol Otol 1971;85:417–30.

Sourdille M. Le traitement chirurgical de l'otospongiose. Rapport au congress Francais d'ORL, Paris, 1935.

Stacke L. Stacke's Operationsmethode. Arch Ohrenheilkd 1893;35:145–6.

Stacke L. Über eine Methode der Plastik zur Deckung der bei der operativen Freilegung der Mittelohrräume entlösten Knochenfläche. Verh Dtsch Otol Ges 1895;2:83–91.

Stacke L. Die operative Freilegung der Mittelohrräume. Tübingen: Pietzcker, 1897.

Stangerup SE, Tos M. Etiological role of acute suppurative otitis media in chronic secretory otitis. Am J Otol 1985;6:126–31.

Stangerup SE, Tos M. Treatment of secretory otitis and pneumatization. Laryngoscope 1986;96:680–4.

Steinbach E, Pusalkar H. Long-term histological fate of cartilage in ossicular reconstruction. J Laryngol Otol 1981;95:1031–9.

Sloltenberg-Lerche. Diskussion, Vortrag Gyergyay. Z Hals-Nasen- Ohrenheilkd 1923;6:392–3.

Strauss P. Der Wiederaufbau der hinteren Gehörgangswand mit homologen Septumknorpel. Erste Ergebnisse. Z Laryngol Rhinol 1974;53:24–32.

Svane-Knudsen V. Mastoidectomy with muscular obliteration modified after Palva. Acta Otolaryngol 1967;suppl224:354–9.

Szpunar J. Reconstruction of middle ear with old radical cavity. Acta Otolaryngol 1973:76:353–9.

Takahashi S, Nakano Y. Tympanoplasty with mastoid obliteration by means of hydroxyapatite granules for aural cholesteatoma. In: Sacristian T, Alvarez-Vincent JJ, Bartual J, Anatoli-Candela F, eds. Otolaryngology and head and neck surgery. Amsterdam: Kugler, 1990:419–42.

Takahashi S, Nakano Y. Tympanoplasty with mastoid obliteration using hydroxyapatite granules. In: Yanagihara N, Suzuki Y, eds. Transplants and implants in otology. Amsterdam: Kugler. 1992:159–63.

Tange RA. The microsaw and fibrin sealant in middle ear surgery. In: Babighian G, Veldmann J, eds. Transplants and implants in otology. Amsterdam: Kugler, 1988:209–11.

Teig E. Personal communication, 1994.

Theissing G, Theissing J. Kurze HNO-Operationslehre ftü Ärzte und Studierende, vol. 2. Stuttgart: Thieme, 1975.

Thies F. Diskussionsbemerkung. Verh Dtsch Otol Ges 1908:120–21.

Thorburn IB. Experience with pedicled temporal muscle flaps in radical mastoid and tympanoplasty operation. J Laryngol Otol 1961;75:885–96.

Tos M. Obliteration of the cavity in mastoidectomy. Acta Otolaryngol 1969;67:516–20.

Tos M. Bony fixation of the malleus and incus. Acta Otolaryngol 1970;70:95–104.

Tos M. Prognosis of hearing loss in temporal bone fractures. J Laryngol Otol 1971;85:1147–59.

Tos M. Bony fixation of the ossicular chain. Arch Otolaryngol 1974a;99:422–7.

Tos M. Production of mucus in the middle ear and Eustachian tube. Ann Otol Rhinol Laryngol 1974b;83:44–58.

Tos M. Tubal function and tympanoplasty. J Otol Laryngol 1974c;88:1113–24.

Tos M. Combined grafts in total reconstruction of old radical cavities. ORL Practica 1977;39:218–26.

Tos M. Operative Therapie bei Otitis mit Erhallung der Hinteren Gehörgangswand (intact wall technique). HNO (Berlin) 1978a;26:217–23.

Tos M. Reconstruction of old radical cavities. Clin Otolaryngol 1978b;3:263–8.

Tos M. Pathology of ossicular chain in carious chronic middle ear diseases. J Otol Rhinol Laryngol 1979a;93:761–80.

Tos M. Middle ear pressure following tympanoplasty for various middle ear diseases: pressure related to follow-up period and retractions. Acta Otolaryngol 1979b;suppl360:131–4.

Tos M. Pathogenesis and pathology of chronic secretory otitis. Ann Otol 1980a;89:91–7.

Tos M. Management of tubal function in reconstructive middle ear surgery. J Laryngol Otol 1980b;94:25–30.

Tos M. Experimental tubal obstruction. Changes in the middle ear mucosa elucidated by quantitative histology. Acta Otolaryngol. 1981;92:51–61.

Tos M. Relationship between secretory otitis in childhood and chronic otitis and its sequelae in adults. J Laryngol Otol 1981;95:1011–22.

Tos M. Modification of combined approach tympanoplasty in attic cholesteatoma. Arch Otolaryngol 1982a;108:772–8.

Tos M. Mastoid pneumatization: a critical analysis of the hereditary theory. Acta Otolaryngol 1982b;94:73–80.

Tos M. Epidemiology and natural history of secretory otitis. Am J Otol 1984;5:459–62.

Tos M. Chronic otitis media and cholesteatoma. In: English G, ed. Otolaryngology, vol. I. Philadelphia: Harper and Row, 1990a;23:1–30.

Tos M. Ventilating tubes for middle ear effusion. In: English G, ed. Otolaryngology, vol. I. Philadelphia: Harper and Row. 1990b;22:1–18.

Tos M, Lau T. Attic cholesteatoma: recurrence rate related to observation time. Am J Otol 1988;9:456–64.

Tos M. Lau T. Late results of surgery in different cholesteatoma types. ORL 1989a;51:33–49.

Tos M, Lau T. Recurrency and the condition of the cavity after surgery for cholesteatoma with various techniques. In: Tos M. Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989b:863–9.

Tos M. Lau T Hearing after surgery for cholesteatoma using various techniques. Auris Nasus Larynx 1989c;16:61–73.

Tos M, Lau T. Long-term hearing results in cholesteatoma. In: Charachon R, Garcia-Ibanez E, eds. Long-term results and indications in otology and otoneurosurgery. Amsterdam: Kugler, 1991:89–94.

Tos M, Stangerup SE. Mastoid pneumatization in secretory otitis: further support for the environmental theory. Acta Otolaryngol 1984;98:110–18.

Tos M, Stangerup SE. The causes of asymmetry of the mastoid air cell system. Acta Otolaryngol 1985a;99:564–70.

Tos M, Stangerup SE. Secretory otitis and pneumatization of the mastoid process: sex differences in the size of the mastoid cell system. Am J Otol 1985b;6:199–205.

Tos M, Tliomsen J. Translabyrinthine acoustic neuroma surgery: a surgical manual. Stuttgart: Thieme, 1991.

Tos M. Stangerup SE, Hvid G. Mastoid pneumatization: evidence of the environmental theory. Arch Otolaryngol 1984a;110:502–7.

Tos M, Stangerup SE, Holm-Jensen S, Sørensen CH. Spontaneous course of secretory otitis and changes of the eardrum. Arch Otolaryngol 1984b;110:281–9.

Tos M, Stangerup SE, Andreassen UK. Size of the mastoid air cells and otitis media. Ann Otol Rhinol Laryngol 1985;94:386–92.

von Tröltsch AF. Lehrbuch der Ohrenheilkunde mit Einschluß der Anatomie des Ohres. Leipzig: Fogel, 1873.

Tumarkin A. Transmeatal altico-antrotomy in chronic tympanomastoid suppuration. Proc R Soc Med 1947;40:761 –77.

Tumarkin A. On the nature and vicissituates of the accessary air spaces of the middle ear. J Laryngol Otol 1957;71:65–99, 137–61.

Tumarkin A. On the nature and significance of hypocellularity of the mastoid. J Laryngol otol 1959;73:34–44.

Turner JL. Obliteration of mastoid cavities by musculoplasty. Laryngoscope 1966;76:465–81.

Turner JL. Soft tissue technique in musculoplasty obliteration of mastoidectomy cavities. Laryngoscope 1972;82:1145–59.

Turgut S, Tos M. Correlation between temporal bone pneumatization location of lateral sinus and length of the mastoid process. J Laryng Otol 1992a;106:485–9.

Turgut S, Tos M. Relation between temporal bone pneumatization and jugular bulb variations. In: Tos M, Thomsen J, eds. Acoustic neuroma. Amsterdam: Kugler, 1992b:257–61.

Utech H. Über die Verwendung von Knorpelgewebe bei Tympanoplastik und Stapeschirurgie. HNO (Berlin) 1961;9:232–3.

Vincencio AB. A retroauricular pedicle skin graft to line the radical mastoid cavity. Arch Otolaryngol 1956;63:296–8.

Wayoff M, Chobaut JC. Deguine C, et al. Les greffes du tympan.

Wehrs RE. Symposium in ear surgery. III: reconstructive mastoidectomy with homograft knee cartilage. 1972;82:1177–88.

Wehrs RE. Results of reconstructive mastoidectomy with homograft knee cartilage. Laryngoscope 1978;88:1912–17.

Weinberg J, Sadé J. Posterior wall atrophy: a late silent complication of combined approach tympanoplasty. Am J Otol 1982;3:315–17.

Whitcher JE, Streit AJ. Musculoplasty and musculotympanoplasty. Laryngoscope 1963;73:185–200.

Whitcher JE, Streit AJ, Hale WP. Musculoplasty and musculotympanoplasty: supplemental report. Laryngoscope 1966;75:246–58.

Whiting T. The modern mastoid operation. Philadelphia 1905.

Wilde RW. Practical observations on aural surgery and the nature of treatment of diseases of the ear. Philadelphia: Blanchard and Leas, 1853:1–53.

Wigand ME. Wiederaufbau von Kuppelraum und Antrum bei der Tympanoplastik. Arch Klin Exp Ohren-Nasen-Kehlkopfheilkd 1967;2:249–53.

Wigand ME. Transcanal mastoidectomy restoring an aerated antrum. Arch Otolaryngol 1970;92:253–357.

Wigand ME. Tympanomeatoplasty with preservation of the bony bridge for cholesteatoma surgery. Clin Otolarvngol 1978;3:415–19.

Wigand ME, Trillsch K. Surgical anatomy of the sinus epitympanum. Ann Otol Rhinol Laryngol 1973;82:378–82.

Wittmaack K. Über die normale Pneumatisation des Schläfenbeines einschließlich ihrer Beziehungen zu den Mittelohrerkrankungen. Jena: Fischer, 1918.

Wittmaack K. Schleimhautkonstitution und Pneumatisation. Arch Ohren-Nasen-Kehlkopfheilkd 1930;132:261–74.

Wolfermann A. Reconstructive surgery of the middle ear. New York: Grune and Stratton, 1971.

Woodruff GH, Henney R. Endaural mastoidectomy: experience in a series of 76 cases. Arch Otolaryngol 1942;35:777–9.

Wright W. Management of otitic cholesteatoma. Arch Otolaryngol 1977;103:144–7.

Wullstein H. The restoration of the function of the middle ear in chronic otitis media. Ann Otol 1956;65:1020–41.

Wullstein H. Die Methode der Decompression des Nervus Facialis von Austritt aus dem Labyrinth bis zu dem Foramen stylomastoideum ohne Beeinträchtigung des Mittelohres. Arch Ohren-Nasen-Kehlkopfheilkd 1958;172:582–7.

Wullstein HL. Funktionelle Operationen im Mittelohr mit Hilfe des freien Spaltlappentransplantates. Arch Ohren-Nasen-Kehlkopfheilkd 1952;161:422–35.

Wullstein HL. Operationen zur Verbesserung des Gehöres. Grundlagen und Methoden. Stuttgart: Thieme 1968.

Wullstein HL, Wulllstein SR. Tympanoplasty: osteoplastic epitympanotomy. Stuttgart: Thieme 1990.

Wullstein SR. Die osteoplastische Epitympanotomie und ihre Resultate. Arch Ohren-Nasen-Kehlkopfheilkd 1972;202:655–8.

Wullstein SR. Die osteoplastische Epitympanotomie und die Pathologic der Mittelohren. 1. Teil: Das operative Vorgehen. Z Laryngol Rhinol Otol 1973:52:34–43.

Wullstein SR. Osteoplastic epitympanotomy. Ann Otol Rhinol Laryngol 1974: 83: 663–9.

Wullstein SR, Schindler K, Dall W. Further observations on application of plasticine in surgery: six year's report. Arch Otolaryngol 1979;223:373–7.

Yamasoba T, Harada T, Nomura Y. Observations of the anterior epitympanic recess in the human temporal bone. Arch Otolaryngol Head Neck Surg 1990;116:566–70.

Yanagihara N, Hinohira Y. Intact canal wall tympanoplasty with reconstruction of the tympanic scute and obliteration of the mastoid antrum in cholesteatoma surgery. In: Tos M, Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989:853–6.

Yanagihara N, Gyo K, Sasaki Y Hinohira Y Prevention of recurrence of cholesteatoma in intact canal wall tympanoplasty. Am J Otol 1993;14:590–4.

Zaufall E. Technik der Trepanation des Processus mastoideus nach Küsterschen Grundsätzen. Arch Ohrenheilkd 1890;30:291–6.

Zini C. Personal communication, 1994.

Zini C, Bacciu R, Scandellari R, Pasanisi E. Intraoperative management of the osseous Eustachian tube: techniques and results. In: Tos M, Thomsen J, Peitersen E, eds. Cholesteatoma and mastoid surgery. Amsterdam: Kugler, 1989:533–41.

Zini C, Sheehy JL, Sanna M. Microsurgery of cholesteatoma of the middle ear. Milan: Ghedini, 1993.

Zöllner F. Die Radikaloperation mit besonderem Bezug auf die Hörfunktion. Z Laryngol Rhinol Otol 1951;30:104–11.

Zöllner F. Hörverbessernde Operationen bei enlzündlich bedingten Mittelohrveränderungen. Arch Ohren-Nasen-Kehlkopfheilkd 1957;171:1–62.

Zöllner F. Tympanoplasty. In: Coates G, Schenck HP, Miller MV. eds. otolaryngology, vol. 1. Hagerstown: Prior, 1959.

Zöllner C, Büsing CM. How useful is tricalcium phosphate ceramic in middle ear surgery. Am J Otol 1986;7:289–93.

Index

A

Acoustic neuroma 48
  translabyrinthine surgery 48
    CSF rhinoliquorrhoea 48
    Sigmoid sinus, bleeding 76–78
Acute otitis media 105
  and meningitis 105
Adhesive otitis
  hypocellularity 50
Aditus ad antrum 31
Aditus block 105
AIDS risk in
  allogenous cartilage 392, 415–416
  allogenous ear drum 128
Air cell area
  planimelric 105
Air cells
  antral 55
  apical 55
  central mastoid 55
  hypotympanic 46, 58
  infralabyrinthine 57
  intersinofacial 55–57
  mastoid 26–28, 55, 86–87
  periantral 31, 55, 88
  perifacial 55, 86
  perilabyrinthine 31, 56, 88–89
  perisinusal 55
  peritubal 45
  precochlear 55–56
  prelabyrinthine 57
  retrosigmoid 55
  sinodural 55, 84
  suprameatal 56
  tegmental 55, 88
  translabyrinthine 56, 88–89
  zygomatic 55
Air cells and secretory otitis 53
Air cell exenteration
  mastoid tip 86
  perifacial 86
  perilabyrinthine 88
    in sclerotic bone 88
    extensive pneumatization 88
Air cell size
  and mastoidectomy 102
  in infancy 103
Air cell tracts
  inferior prelabyrinthine 55
  infratubal 46
  mastoid 55
  perilabyrinthine 56
  petrous apex 55–56
  petrous bone 55–56
  precochlear 56
  sublabyrinthine 57
  variations 51
Allogenous ear canal wall 338
Allogenous ear drum 336–338
  AIDS risk 128
  cholesteatoma removal 128
Allogenous graft
  bone
    obliteration 401–403
  costal cartilage in
    scutumplasty 148
    obliteration 384. 389–392
  dura
    ear canal wall reconstruction 325–327
  ear canal wall transplantation 338
  ear drum 333, 336–338
  ear drum-malleus 332
  ear drum-malleus-incus 336
  knee cartilage in
    ear canal wall reconstruction 333
    scutumplasty 141–142
  septal cartilage in
    ear canal wall reconstruction 331–332
    obliteration 389–391
    scutumplasty 141–142
Allograft ear drum-ossicle block 336
Alluminium foil template 331, 340
Anacusis
  postoperative 104
Anterior attic bony plate 36–37
  removal 123–127, 223–224
Anterior buttress 232
Anterior malleolar ligament 40–43
Anterior transcortical atticotympanotomy 122–124
Anterior transmeatal atticotympanolomy 125–127
Antrotomy 96, 214–216
Antrum 30–31
  entering technique 64, 82
  in sclerotic mastoid 30, 83
Antrum exclusion technique (Olaizola) 227–228
Antrum threshold 110
Approaches in mastoidectomy
  endaural 11–13, 262–265
    history 262–263
  retroauricular 11–15, 248–249
Atelectasis 46
  and mastoid ventilation 59
Atrophy of the ear canal wall
  after intact canal wall mastoidectomy 151
Atrophy of the temporalis muscle
  after obliteration 362 363
Atrophic ear drum 61
Attic 35–36
  anterior 36
  lateral 35–36
  medial 35
  posterior 35
  unroofing 123–124
Attic cholesteatoma see cholesteatoma
Attic elimination technique (Olaizola) 227–228
Attic in canal wall down mastoidectomy
  closed 269–270
  obliterated 272–273, 287–293
    with bone chips 273
    with bone paté 273
    with cartilage 272
    with fibrous tissue 273
  open 239–240, 244, 253, 271–273, 287–293
  ventilated 201, 258–259, 268–270, 272, 287–293
Attic obliteration
  partial 343–345
  total 343–345
Attic reconstruction
  in canal wall down mastoidectomy 278–282, 290–292
    with preserved bridge 282–284, 291–292
Attic retraction 7–8
  postoperative 147–152
    appearance 149–150
    causes 147–148
    mechanism 148–149
    progression 150–152
Atticoanlrotomy 4–5
  transcortical route 4
  transmeatal route 4
  Barany modification 107
Atticotomy 2–4, 7–9, 158–170, 172–173
  displaced bridge 4, 183–187
  partially removed bridge 3
  preserved bridge 2
  totally removed bridge 2, 7–9
  transmeatal
    Rosborg 127
    Tos 156–165
Atticotomy closure
  bone 173–174
  cartilage 172–173
  fascia 173–182
Atticotympanotomy
  anterior 122–123
    transcortical 122–123, 166–168
    transmeatal 125–127, 166–168, 170–171,222–225
  lateral 113–114
  posterior 15, 33–34, 115–121
Autogenous grafts
  bone in
    attic reconstruction 343–345
    atticotomy closure 173–178, 181–183, 187
    ear canal wall reconstruction 333–335,343–345,441–413
    Farrior's mastoidectomy 224, 226
    obliteration 154, 210, 386–387, 391,393–401,407–409, 411–413
    scutumplasty, 143–145, 151–153

  - bone paté in
    - attic obliteration 273
    - attic wall osteoplasty 213
    - cavity obliteration 210, 226, 386, 392, 396–397, 400–401
    - ear canal reconstruction 336–337, 341
    - scutumplasty 145–147
  - conchal cartilage in
    - attic obliteration 272, 275
    - attic reconstruction 276–277. 344–345
    - atticotomy closure 173, 181–188
    - Bondy operation 234–235
    - cavity obliteration 153, 383–389
    - ear canal reconstruction 153, 329–331
    - Olaizola techniques 227–229
    - partial obliteration 293
    - scutumplasty 138–139, 141, 151, 155
  - fascia in
    - attic obliteration 273
    - attic reconstruction in
      - missing bridge 238–240, 242, 244, 253–255
      - preserved bridge 278–283
    - atticotomy covering 172, 181–182,186
    - cavity covering 278–292, 301–306,308,309–314,323
    - canal wall reconstruction 325–333, 337–345
    - cavity obliteration 248–249, 253–254, 360, 363, 366, 368, 371,380,385–391,395–412
    - cavity reconstruction 268–269
    - Farrior mastoidectomy 225
    - mobile bridge technique 202
    - osteoplastic epitympanotomy 204
    - osteoplastic mastoidectomy 199
    - Paparella technique 283–284
    - partial cavity obliteration 293, 310–312, 344–345
    - temporary canal wall removal 207
    - tympanic cavity reconstruction 261–262
  - fatty tissue in
    - partial obliteration 414–415
    - total obliteration 414–415
      - behind intact canal wall 414
      - in canal wall up mastoidectomy 414
      - in canal wall down mastoidectomy 415
  - fibrous tissue 273
  - heterotopic skin see skin grafts
  - muscle (free) 224, 283
  - muscle (pedicled) see obliteration
  - pedicled fascia 336
  - periosteum in
    - canal wall reconstruction 341–343
    - mastoid tip removal 321–322
    - scutumplasty 143
    - Wigand's technique 219–221
  - perichondrium 137–140
  - tragal cartilage in
    - attic obliteration 272, 275
    - attic reconstruction 276–278, 334–335
    - atticotomy closure, 171, 187–188
    - Bondy operation 234–235
    - cavity obliteration 383–391
    - canal wall reconstruction 328–331, 334, 390, 399–401, 403
    - Farrior technique 226–229
    - Olaizola technique 227–229
    - partial obliteration 292
    - scutumplasty 139–140, 146, 151, 153–154
    - Wigand's technique 219

B

- Babighian posterior and attic wall osteoplasty 211–213
- Barany conservative radicaloperation 106
- Baron rules on cholesteatoma matrix 234–235
- Bellucci wide external auditory canal techniques 229
- Bezold's abscess 98
- Bill's bar 48
- Bill's island 72
- Biocompatible materials in
  - cavity obliteration 404–413
    - anorganic bone 404
    - ceramics 405–413
    - ceravital 339
    - glass ionomer cement 339
    - hydroxyapatite 108, 404, 409–412
    - metacrylate 404
    - plaster of Paris 405–407
    - Triosite 408–409
  - ear canal reconstruction 339–342
  - scutumplasty 146–147
- Black's ear canal wall reconstruction 341–342
- Blood in obliteration 380
- Bondy's operation 58, 231–235, 257
- Bone cement *see* ionomer cement and glass ionomer cement
- Bone grafts *see* allogenous or autogenous bone
- Bone paté 146–147, 135, 204, 210, 213, *see* also autogenous grafts
- Bony annulus *see* bony bridge *see* also scutum
- Bony bridge
  - displaced 183–187,214–217,220, 246
  - removed 9, 267
  - reconstruction 267, 344–345
  - resorbed in
    - attic cholesteatoma 2–3, 183–188, 256
    - sinus cholesteatoma 3
  - preserved in
    - atticotomy 2–4
    - conservative radical operation 106–108, 239–240, 245–246, 275–283
- Bony ear canal wall *see* ear canal wall
- Bony fixation of the malleus 36, 104
  - in cortical mastoidectomy 104
- Botey's incision 214
- Bottle neck of the air flow 40
- Brask obliteration method 391
- Brunar's intact canal wall mastoidectomy 109

C

- Cancellous bone in obliteration 393–395
- Canal wall up mastoidectomy
  - classic 15, 19, 106–155
  - modifications 16–19
    - Morimitsu modification 18
    - Tos' modification 16–18, 156–195
- Carotic canal 46–47, 58
- Carotid artery 44–64, 58–59
- Cartilage graft *see* autogenous or allogenous cartilage
- Cavity obliteration *see* obliteration
- Ceravital 339
- Cerebellopontine angle 48
- Childhood cholesteatoma 90–95
- Cholesteatoma
  - matrix
    - dissection 85, 241–244, 253–261
      - Sanna technique 234
    - preservation
      - indications (Baron) 235
  - removal in
    - atticotomy 7–9
    - atticoantrotomy 5–7
    - Bondy's operation 5–7
    - canal wall down mastoidectomy
      - attic cholesteatoma 241–242, 253–257
      - sinus cholesteatoma 242–243, 258–261
      - tensa retraction cholesteatoma 242–244
    - children 90–95
    - classic intact canal wall mastoidectomy 128–136
      - attic cholesteatoma 90–95
        - conservative removal 90, 129
          - intact ossicular chain 131–133
          - disrupted chain 133–135
        - Marquet's method 128
      - sinus cholesteatoma 135
      - tensa retraction cholesteatoma 136
    - modified combined approach tympanoplasty (Tos)
      - attic cholesteatoma 157–167, 168–176,178–180
      - sinus cholesteatoma 189–191
      - tensa retraction cholesteatoma 192–193
    - osteoplastic epitympanotomy (S. Wullstein) 203
    - perilabyrinthine cells 79
    - sinodural angle 85
    - Wigand's tympanomeatoplasty 218
    - types
    - acquired
      - attic cholesteatoma 120, 130, 133–134
      - sinus cholesteatoma 135, 189
      - tensa retraction cholesteatoma 135, 193
    - inclusion 92
    - recurrent 147–152, 194–195
    - residual 92, 194–195
- Cholesteatoma in childhood 90–95

Chorda tympani 48
  in posterior atticotympanotomy 116–117
Chronic otitis media
  and perilabyrinthine air cells 90
Classic intact canal wall mastoidectomy 106–155
Cialit 332, 389
Citelli emissarium 29
Closed technique 14, 287–293
Coalescent mastoiditis 98
Cochlear aqueduct 60
Cochlear implantation 34
Cochleariform process 43–44
Cog *see* anterior attic plate
Columella see tympanoplasty, type III
Combined approach mastoidectomy 106–111
Complications in obliteration 380–382
Complete mastoidectomy 96
Conchal cartilage removal (conchoplasty) 262. 265, 300–311, 379–380, 387–390, 401
Congenital atresia 286
Congenital mucosal folds 40–42
Conservative radical operation *see* radical operation
Constricted mastoid process 60
  anteriorly positioned sinus 60
Cortical mastoidectomy *see* mastoidectomy
Creutzfeldt-Jakob disease
  in allogenous ear drum 128
Cribriform area 24
  in mastoiditis 99–100

D

Dawlatly's obliteration method 359–361
Development of air cells 54
Digastric crest 28, 32–33, 47, 87, 316–321
Donaldson's line 32
Dural defects
  repair of 66–68
    bipolar coagulation 67
    cartilage 68
    fibrin glue 67–68
    triple seal 68
  CSF leak in 66
  avoidance of 68–69

E

Ear canal packing 327, 354
Ear canal stenosis
  in obliteration 382
Ear canal skin flaps, damage 63
Ear canal skin grafts
  pedicled 299–303
Ear canal wall (bony)
  permanent removal 230–245
  temporary
    displacement 196–213
    mobilization 196–202
    removal 202–213
Ear canal wall reconstruction
  partial 324, 343–345
  total 324–345
  cavity ventilation
  criteria 324–325
  materials
    allogenous cartilage
      knee 332–333
      septal 331–332
    allogenous ear canal wall 338
    allogenous dura 336–337
    autogenous bone
      iliac crest 335
      mastoid cortex 333–334
    autogenous cartilage 329–331
    bone paté 335–337
    ceramics
      bioglass 339
      ceravital 339
      glass ionomer cement 339
      hydroxyapatite 339–342
      proplast 339
    fascia 325–328
    Palva flap 325–327
    periosteum 219–221
Ear drum
  atrophy 61
  retraction 61
  sequelae 61
  tympanosclerosis 61
Elbrønd obliteration method 355
Emissary vein
  bleeding from 77
Emissarium
  mastoideum (Citelli) 27
  occipitale (Santorini) 25
Endaural radical mastoidectomy 262–263
Endaural mastoid surgery 262–283
Endolymphatic sac 32–33
  surgery 69
Epitympanic recess *see* epitympanic sinus
Epitympanic sinus
  anatomy 36–38
  entering 124–125, 166–167
  types 36–38
Eminence of the tensor tympani muscle 44
Eustachian tube
  anatomy 44–45
  bouginage 45
  cholesteatoma 45
  isthmus 45
  surgical closure 10
  tympanic orifice 44–45
Exploratory cortical mastoidectomy 105
Extensive pneumatization and canal wall up 50

F

Facial nerve 32–34, 48–49
  anatomy 32–34, 48–49
  decompression 34, 110
  exposure 48–49
  external genu 32–33, 48
  geniculate ganglion 48
  horizontal portion 32–33, 48
  second genu 48
  second part 48
  skeletonization 119–121
  vertical part 48
    in posterior atticotympanotomy 116–121
    injury in posterior atticotympanotomy 120
  vertical portion 48
    barber pooling 117
Facial paralysis
  in simple mastoidectomy 103
Facial ridge
  in canal wall down mastoidectomy
    high 231. 411–413
    low 231, 233
    removal 237–238
Facial recess 33–34, 110, 115
  in posterior atticotympanotomy 116–117
Facial sinus 33–34, 38
Fallopian canal 48
Farrior's mastoidectomy techniques 21, 222–227, 383
Farrior's meatoplasty 304
Farrior's obliteration methods 379, 380
Feldmann's microsaw 207, 212–213
Feldmann's osteoplastic meatoantrotomy 206–209
Fenestration 51
  and mastoid ventilation 51
Fibrin glue in
  ear canal reconstruction 206, 328, 337
  obliteration 391–392, 396, 408, 412
  osteoplastic epitympanotomy 109, 204
  scutumplasty 140, 206
  tympanomeatoplasty 219
Fibrous annulus
  removal in classical radical operation 10
Fisch's meatoplasty 308
Fleury's meatoplasty 304–305
Frame *see* scutum
Formaldehyde 389
Freerichs and Williams obliteration method 349–350

G

Gas resorption and mucosal area 51
Gaussian distribution
  on air cell size 51
  on tubal disease 52–53
Geniculate ganglion 44, 48
Gerlach's scutumplasty method 143
Gerlach's temporary meatotomy 202–203
Gersdorff obliteration method 408–409
Gigli microsaw 205
Glass ionomer cement 206–207, 213
Glossopharyngeal nerve 43
Graft materials, see autogenous or allogenous grafts
Greater petrosal nerve 43–44. 48
Grote's ear canal wall reconstruction method 339, 340
Guilford's mastoid tip removal 315–317
Guilford's obliteration method 354, 374

H

Heermann's palisaded cartilage mastoidplasty 388–389
Hereditary theory on pneumatization 51
High jugular bulb 46
High tone loss
  in cortical mastoidectomy 103–104
Hilger and Hohmann obliteration method 375–376
Honda obliteration method 155, 401
Honda scutumplasty method 149
Hong Kong flap 363
House-Sheehy retractor 211, 157, 263. 388
Hydroxyapatite 146–147, 154, 339, 342
Hyperplastic mucosal fold 40–42
Hypocellularity 50–53
Hypotympanic sinus
  anterior 46–47
  posterior 46–47
Hypotympanotomy 121
Hypotympanum 26
  anatomy 46–47
    bony septa 46
  jugular bulb protrusion 46–47
  retraction in
    sinus cholesteatoma 46
    tensa retraction cholesteatoma 46
Hystoacryl glue 206–207

I

Inclusion cholesteatoma 92
Incudal fossa 33–34
Incus 35–36
  extrusion in simple mastoidectomy 103
  subluxation in simple mastoidectomy 103
Incus columella *see* columella
Incus interposition *see* tympanoplasty type II
Inferior sinus *see* sinus tympani
Inferior transmastoid hypotympanotomy 121
Infratubal air cell tract 46–47
Inorganic bone 404
Intact bridge mastoidectomy techniques (Paparella) 21–22, 282–284
Intact canal wall mastoidectomy *see* canal wall up mastoidectomy
Intact soft ear canal wall mastoidectomy 106–108
Intermedius nerve 48
Interposition *see* tympanoplasty, type II
Ionomer cement 206–207, 213, 339
Isthmus tympani *see* tympanic isthmus

J

Jacobsen's nerve 43–44
Jansen's posterior tympanotomy 106
Jugular bulb
  high positioned 46–47
Jugular dome 47
Jugular vein (internal) 47

K

Körner's flap 299–301
Körner's meatoplasty 299, 306, 310
Körner's septum 30–31, 82–83
  absence of 31
  in canal wall down mastoidectomy 248–250
  in simple mastoidectomy 83, 101
  in small children 99–100

L

Labyrinth 31–32
Labyrinthine fistula 91
Lateral atticotympanotomy 113–114
Lateral malleolar ligament 43
Lateral tympanic sinus 38–40
Lesser superficial petrosal nerve 43–44
Lingual nerve 45
Lyophilized dura in
  attic reconstruction 345
  ear canal wall reconstruction 335–339

M

Macewen's triangle 25
Malleolar ligaments 40–43
  anterior 41
  posterior 43
Malleostapediopexy 219
Marsupialisation of cholesteatoma 5–6, 234–235, 257
Mastoid abscess 98
  drainage 98, 101
Mastoid antrum *see* antrum
Mastoid air cells 55
Mastoid emissary 23
Mastoid foramen 23–24
Mastoid osteoplasty (Schiller) 393–394
Mastoidplasty 393
Mastoid process
  surface 23–25
Mastoid tegmen *see* tegmen mastoidei
Mastoid lip
  apical air cells 55, 86–87
    exenteration 82, 86–87
  removal 319–323
    Guilford's method 315–316
    retroauricular approach 318–320
  obliteration with
    muscle 318
    periosteum 321–322
Mastoidectomy
  drilling techniques 62–63
  drilling damage
    avoidance of 62–63
    to canal skin 63
    to middle fossa dura 63–64
    to soft tissue 63
  types
    atticotympanotomy and mastoidectomy (Farrior) 222–226
    complete 96
canal wall down 14–22, 231–245
  Bondy's operation 5–6, 14, 231–235
    Sanna's modification 234–235
    surgical technique 231–234
    reconstruction 333
  classic radical 10, 231
  conservative radical 10
  endaural mastoidectomy 263–284
    reconstruction 268–277
    surgical technique 263–268
  modified radical 10
  transcortical mastoidectomy 11–12, 230–255
  transmeatal mastoidectomy 12, 247–261
    cholesteatoma removal 253–255
    reconstruction 255
    surgical technique 248–253
canal wall up 14–22
  classic intact canal wall 14–15, 19, 106–155
    modifications 14–19
      Brunar's modification 109
      Morimitsu modification 18, 125–127
      Tos' modification 16–19, 156–195
    surgical technique 110–120
    obliteration 377–378
  modified combined approach tympanoplasty (Tos) 14,18,157–195
    philosophy 194–195
    reconstruction
      in defective chain 178, 180–183, 186–187, 192–193
      in intact chain 172–174
    surgical technique 156–170
      atticotomy 158–163, 166,167, 176
      otosclerosis drilling 157–158
      posterior tympanotomy 157–158
cortical 9, 102–105
  complications 103
  indications 102
  surgical technique 63–83. 102
exploratory 105
Farrior's transcortical mastoidectomy
  reconstruction 225–226
  surgical technique 222–224
intact bridge tympanomastoidectomy
  (Paparella) 282–283
Olaizola on demand technique 227–228
osteoplastic mastoidectomy (Schnee) 196–198
osteoplastic epitympanotomy (S.Wullstein) 202–203
  cholesteatoma removal 203
  reconstruction 203–204
  surgical technique 203–205
osteoplastic meatoantrotomy
  (Feldmann) 206–207
posterior and attic wall osteoplasty

    - (Babighian) 211–213
    - Richards mobile bridge technique 200–202
    - simple 9, 96–101
      - complications 103
      - incidence 97
      - indications 98
      - surgical technique 99–101
    - soft ear canal wall preservation 106–108
    - tympanomeatoplasty (Wigand) 214–221
      - cholesteatoma removal 218
      - reconstruction 218–221
      - surgical technique 214–217
    - tympanomastoidectomy (Paparella) 282–283
    - wide ear canal mastoidectomy (Bellucci) 229
  - Routes
    - retrograde 12–13, 256–261
    - transcortical 11–13, 231–245
      - "inside-in" 11–12, 247–253
      - "outside-out" 11–12, 247, 255–261
    - transmeatal 12,247–251
- Mastoiditis
  - coalescent 98
  - acute 98
- Meatal stenosis
  - after mastoidectomy 104
- Meatoplasty 286, 289–290, 303–311
  - cavity obliteration 288, 310–313
  - methods
    - Farrior 304
    - Fisch 309
    - Fleury 304–305
    - Körner 299–300, 304–305
    - Portmann 305–307
    - Sheehy 309
    - Stacke 302–305
    - Teig 312–314
- Mcalomastoidplasty 286
- Meatotomy, temporary (Gerlach) 202–203
- Meningitis 97
  - in acute otitis 105
- Mercke's obliteration method 210
- Mesenchyme 54
- Mesotympanum
  - anatomy 43–44
- Meurmann's obliteration method 372–373
- Meuser's obliteration method 404–405
- Middle cranial fossa dura
  - exposure 63–64
  - low position 64
- Middle cranial fossa dural plate 27–28, 63–66
- Middle ear mucosa 41–42, 52–53, 61
  - histology 41–42
- Migration of keratin
  - from cholesteatoma sac 7
- Modified combined approach tympanoplasty (Tos) 16–19, 156–195
- Morimitsu anterior atticotympanotomy 125–127
- Mosher flap 364
- Mucosal folds 40–42
  - congenital 40–42
  - incudal 40
    - lateral 40
    - medial 40
    - superior 40
  - interossicular 41
  - malleolar 40
    - anterior 40–41
    - lateral 40–41
    - superior 40–41
  - obturator fold 41
  - postinflammatory 41–42
  - stapedial fold 41
  - tensor tympani fold 41
- Mucous glands 41, 52–53
  - in normal children 42, 53
  - in normal adults 42, 53
- Myringoplasty in
  - canal wall up mastoidectomy
    - classic 137–151, 290
    - modified 172–173, 178, 181–183, 186–188, 290
  - canal wall down mastoidectomy 268–274, 290–291
  - Farrior's mastoidectomy technique 225–226
  - tympanomeatoplasty (Wigand) 219–221,226
- Müsebeck classification of antrum-mastoid operations 286

N

- Nakano obliteration method 411–413
- Naumann obliteration method 377, 380
- Neo–Wittmaackians 51
- Normal variant theory *see* hereditary theory

O

- Obliteration 14
  - behind intact canal wall 153–155, 377–378, 383–384
    - partial 14, 155
    - total 14, 153–155, 383–385
      - cartilage 383–384
      - fatty tissue 414–415
  - behind open attic 226
  - Farrior's techniques 385, 415
  - mastoid cavity 286–289, 346–416
    - biocompatible materials
      - anorganic bone 404
      - ceramics 405–413
        - ceravital 405
        - friolit 405
        - glass ceramics 405
        - glass ionomer cement 413
        - hydroxyapatite 409–412
        - plaster of Paris 405–407
        - plasticine 408
        - plastic bone cement 404
        - tricalciumphosphate 405
        - triosite 408–409
      - methacrylate 404–405
    - bone
      - allogenous 401–403
      - autogenous 393–401
        - heterotopic 393–395
          - iliac crest 393–395
          - tibial crest 395
        - ortotopic 396–401
          - chips 396–401
          - plates 396–401
    - bone paté 335, 397, 400–401
    - cartilage
      - allogenous 389–392
        - crushed 390–391
        - costal 392
        - knee 389
        - plates 390
        - septal 390
      - autogenous 383–389
        - palisaded 380–389
    - combined grafts 384–387, 390, 414–415
    - fatty tissue 414–415
      - in combined grafts 414–415
    - muscle flaps 310–314, 346–381
      - anteriorly based 364–372
        - Mosher 364–365
        - Palva 365–372
        - Popper 364–365
      - combined flaps 382
      - complications 380–381
      - inferiorly based 372–380
        - Farrior 379
        - Guilford 374–375
        - Hilger and Hohmann 375–377
        - Meurmann 372–373
        - Naumann 377–378
      - posterosuperiorly based 359–362
        - Dawlatly 360–361
        - Withcher's tripartite 361–362
      - superiorly based 346–359
        - Elbrønd's 355–356
        - Freerichs' 349–350
        - Guilford's 354
        - Rambo's 346–349
        - Tos' bipartite 351–354
        - Turner's 356–359
    - partial 291–292, 371
    - temporalis muscle fascia 360, 363
    - temporary bony ear canal wall removal 210, 385, 415
    - total 292
- Olaizola obliteration method 409–410
- Olaizola on demand techniques 227–229
- Open cavity 294–314
  - epithelial covering 294–303
- Open technique 14, 287–293
- Ossicular chain pathology in
  - attic cholesteatoma 133
  - sinus cholesteatoma 135
  - tensa retraction cholesteatoma 136
- Ossiculoplasty methods
  - in canal wall down mastoidectomy 268–273
- Osteoclastic activity
  - in pneumatization 54
- Osteoplastic epitympanotomy (S. Wullstein) 202–240
- Osteoplastic flap 197
- Osteoplastic meato-antrotomy (Feldmann) 206–209
- Osteoplastic mastoidectomy (Schnee) 196–199
- Otosclerosis drilling 157, 192, 260–267

P

Palva flap 153–154, 210, 286, 310–314, 325–327, 331, 337,342, 365–370, 383–391, 397–398, 401–405, 409–412
Palva's obliteration method 365–371
Paparella intact bridge tympanomastoidectomy 21, 283–284
Pedicled fascia graft 363
Periantral air cells 81–83
Perilabyrinthine air cells 52. 88–90
  infralabyrinthine 52
  intralabyrinthine 52
  petrosal crest 52
Perilabyrinthine air cells
  retrolabyrinthine 52–53
  sublabyrinthine 52
  supralabyrinthine 52–53
  translabyrinthine 52
Perilabyrinthine cells and cholesteatoma removal 91–95
Periosteal flaps 341–342
Petrous apex 29
Petrosal nerve *see* greater petrosal nerve 44
Petrositis, acute 99
Petrosquamous lamina *see* Körner's septum
Petrotympanic fissure (Gasseri) 44–45
Planimetry 51–54, 103
Plaster of Paris in cavity obliteration 405–406
Plester – antrostomy 285
Pneumatization
  degree and surgical techniques 50
    canal wall down mastoidectomy 50
    canal wall up mastoidectomy 50
  diminished 51
  environmental theory 51–52
  hereditary theory 51–52
  of petrous apex 56
  temporal bone 51–52
Pneumatization process 54
  histology 54
  in early childhood 54
Ponticulus 39
Popper obliteration flap 364
PORP (partial replacement ossicular prosthesis) 284
Portmann's meatoplasty 306–308
  large, five-flap 306–308
  small, three-flap 306–308
Portmann's temporary removal of the bony ear canal wall 205–207
Posterior atticotympanotomy 15, 33, 106, 109–111, 115–121, 200–201
  complications 108–109
    facial nerve 108
    sensorineural hearing loss 108
  extended 120–121
    in absent incus 120, 206
  routes
    lateral 115
    medial 116
Posterior buttress 33–34, 40, 119
Posterior fossa dura
  exposure 90
Posterior fossa dural plate 28–29, 33
Posterior hypo-tympanotomy 110
Posterior malleus pouch (von Tröltsch) 43
Posterior tympanotomy in CAT *see* posterior atticotympanotomy
Posterior tympanic sinus 39
Posterior tympanum 38–40
Postinflammatory adhesions and mucosal fold 40–41
Precochlear air cells 58
Prelabyrinthine air cells 58
  intercaroticocochlear 58
  pericarotid 58
  peritubal 58
Pretympanic recess 45
Protympanum 44–45
Prussak's space 42
Pyramidal eminence 39

R

Radical operation 10, 285
  classical radical 10, 285–286
  conservative radical 10, 285–286
  modified radical 10
Rambo obliteration method 346–347
Reciprocating microsaw (Feldmann) 201
Reconstruction techniques
  closed 286–288
    in canal wall up mastoidectomy 286
    in canal wall down mastoidectomy 286–288
  open 288
Recurrent otitis media 105
Re-pneumatizalion in
  canal wall up mastoidectomy
    classic 14
    modified 14
  Farrior's mastoidectomy 223–226
  Wigand tympanomeatoplasty 214–221
Residual cholesteatoma
  frequency of 194
Retraction 147–155
  postoperative 219–220, 147–155, 181–184, 188, 289
    selfcleansing 219
Retraction into hypotympanic sinus 46
Retraction pockets 147–155, 181–184, 188
Retroauricular subperiosteal abscess 98
Retrograde mastoidectomy 255–258
Retrograde mastoidectomy on demand 258–261
Richard's mobile bridge technique 200–202

S

Sakai scutumplasty method 145
Sanna's modification of Bondy's operation 234–235
Santorini emissarium 25
Schiller's mastoid osteoplasty 393–395
Sclerotic mastoid process 60, 88
Sclerotic temporal bone 88
Scutum 35
  removal 4
  repair *see* scutumplasty
  resorption 4
Scutumplasty criteria 144
Scutumplasty techniques
  biocompatible materials
    hydroxyapatite 146–147
  bone
    autogenous 143–145
      plates 145
      curls 144
  bone paté 146
  cartilage, autogenous 137
    conchal 137, 139–140
    perichondrium 139
    septal 139
    tragal combined graft 137–139
    tragal sliced 140
  cartilage, allogenous
    costal 142
    knee 141–142
    septal 141
Second look surgery 110, 200
Secretory otitis media
  air cell system 50–54
  epidemiology 41, 51–53
  grommet discharge 104
  histopathology 42, 53
  hypocellularity 51
  incidence 41
  pneumatization in 54
  protracted 104–105
Semicanal for the tensor tympani muscle 43–45
Semicircular canals
  lateral 31–33
  posterior 31–33
  superior 31–33
Sensorineural hearing loss
  postoperative 103–104
Sheehy's meatoplasty 307
Sheehy's posterior vascular strip elevation 111
Sigmoid sinus 28–29
    anterior position 28, 72
    bleeding from 76–78
    laceration of 76–78
  exposure of
    total exposure 69–75
    skeletonization 70–71
      Bill's island 72
      egg shall method 73
  obliteration
    intraluminal 78
    extraluminal 78
    intra and extraluminal 178
Simple mastoidectomy *see* mastoidectomy
Sinodural angle 29
  skeletonization of 84–85
  drilling 84
  bleeding from 86
  cholesteatoma dissection from 86
Sinus cholesteatoma removal 135–136, 189–191 *see* cholesteatoma
Sinus tympani 39, 41
Skin grafts 294–303
  split skin 294–295
  full-thickness 295–299

  pedicled 295–299
Skin-subcutis graft 295–299, 377
Skull base surgery and sigmoid sinus exposure 69
Soft ear canal preservation method 106–108
Sphenopalatine ganglion 89
Stacke flap 214–216, 301
Stacke's meatoplasty 302–304
Staged surgery in cholesteatoma 154
  scutum repair 148, 154
Styloid complex 46–47
Stylomastoid foramen 48
Superior petrosal sinus 29
Suprameatal spine 23–25
Supratubal recess 36–37
  entering 124
Supratubal space *see* epitympanic sinus
Surdille flap 302
Svane-Knudsen's partial obliteration 371

T

Tegmen
  antri 27
  mastoidei 27
  tympani 27
Tegmental air cells 55
Teig's meatoplasty 312–313
Temporal bone
  mastoid part 23, 30
  petromastoid part 23, 30
  squamous part 23, 30
  tympanic part 23
Temporal line 23–25
Temporalis muscle, vascularization 362–363
Temporary meatotomy (Gerlach) 202–203
Tendon of the tensor tympani muscle
  anatomy 43
Tensor tympani
  eminence 37–38, 43–47
  fold 36–37
  muscle 36–38
Thornburn's obliteration method 347–348
Tos' obliteration method 351–354
Tos' modified combined approach tympanoplasty 156–195
Transcanal atticotympanotomy (Farrior) 21, 383
Transcortical anterior atticotympanotomy 121–124, 165–167
Translabyrinthine surgery
  exposure of the dura 64
Transmeatal anterior atticotympanotomy
  and transcortical mastoidectomy (Farrior) 222–226
Transmastoid hypotympanotomy 121
Transmastoid tympanoplasty 106, 122
Transmeatal anterior atticotympanotomy (Morimitsu) 125–126
Transmeatal anterior atticotympanotomy (Farrior) 125
Transmeatal atticotomy (Rosborg) 126
Transversal crest 48
Trautmann's triangle 32
Tubal bouginage 177
Tubal dysfunction
  incidence in children 52–53
Tubal recess 37
Turner's obliteration method 356–359
Tympanic bone 25–26, 46–47
Tympanic diaphragm 40–41
Tympanic isthmus 35, 40
  anterior 35, 40, 43
  posterior 43
Tympanic nerve *see* Jacobsen's nerve
Tympanic ring 46
Tympanic sinuses
  lateral 38–39
  posterior 38–39
  sinus tympani 39
Tympanomastoid suture 23
Tympanomastoidectomy *see* mastoidectomy
Tympanomeatoplasty *see* mastoidectomy
Tympanometry
  in secretory otitis 52–53
Tympanoplasty, type I in
  Bondy operation 233–235, 268–269
  canal wall down mastoidectomy
    removed bridge 238, 268–269
    partly removed bridge 239–240
    preserved bridge 245, 252, 278–279
  canal wall up mastoidectomy
    classic 125–127, 132. 137, 140, 142, 145
    modified 167, 172–173, 186
  mobile bridge technique 201
  osteoplastic mastoidectomy 199, 209
Tympanoplasty, type II with
  interposition of
    bone in
      canal wall down mastoidectomy
        bridge removed 301, 304, 323
          malleus present 239, 269
          malleus head absent 239, 244
          malleus missing 272–273
        bridge partly removed 202, 281–282
        bridge preserved 278
      canal wall reconstruction 325–327, 332
      canal wall up mastoidectomy
        classic 141, 154
        modified 178
      obliteration 354, 367, 378, 387, 389–391,397
    cartilage 154, 284
    hydroxyapatite 154, 283
    ionomer glass cement 339
    incus in
      canal wall down mastoidectomy
        bridge partially removed 240
        bridge preserved 240, 278
        bridge removed 239, 244, 292, 294, 302, 323
          malleus present 239, 269
          malleus head absent 239, 244, 291–293
          malleus missing 222
      canal wall reconstruction 325–327, 330–331, 384–387, 389–391
      canal wall up mastoidectomy
        classic 141, 147, 154
        modified 178, 181
      Farrior's technique 226–227
      mobile bridge mastoidectomy 384–387, 389–391
      obliteration 352, 367–368, 371, 378
  malleostapediopexy 219, 273
  myringoincudopexy 242, 254–255, 302
  myringostapediopexy 273
Tympanoplasty, type III with
  columellae of
    bone in
      attic reconstruction 343–345
      canal wall down mastoidectomy
        malleus present 260–261, 310–311
        missing malleus 253, 273–275
        missing malleus head 271, 274, 314
      canal wall reconstruction 333
      obliteration
        malleus present 412
        missing malleus 398–399, 404–405, 407
      osteoplastic epitympanotomy 204
      temporary canal wall removal 207
    incus in 259–260, 314, 343–345
      attic reconstruction 343–345
      canal wall down mastoidectomy
        malleus present 260–261, 310–312
        missing malleus 253, 273
        missing malleus head 271, 274,314
      obliteration
        malleus present 412
        missing malleus 398–401, 403–404
        missing malleus head 404–405
      osteoplastic epitympanotomy 204
      temporary canal wall removal 207
Tympanoplasty, type IV 273
Tympanosquamous suture 23–27
Tympanotomy
  anterior 34
  inferior 34
  posterior 34
  superior 34
von Tröltsch posterior malleus pouch 43

V

Ventilated attic 287–293
Ventilation
  mastoid cavity 106–107, 187, 339
Vertical crest 48
Vestibular aqueduct 33
Vestibule 33

W

Wehrs' scutumplasty 108
Whitcher's obliteration method 361–362
Wigand's tympanomeatoplasty 214–221
  and obliteration 383
Wullstein's antrotomy 214
Wullstein's lower inspection hole 109–110
Wullstein's osteoplastic epitympanotomy 202–204

Z

Zini scutumplasty 143
Zygomatic root 106
Zygomatic subperiosteal abscess 98